PAGE XXXII

Volume 51. Number 4. | December, 1937. Pages 367-486 | $4.00 a Year. $1.25 a Number.

JOURNAL

OF THE

New England Water Works Association.

ISSUED QUARTERLY.

PUBLISHED BY
THE NEW ENGLAND WATER WORKS ASSOCIATION,
613 Statler Building, Boston, Mass.

Entered as second-class matter September 23, 1903, at the Post Office at Boston, Mass., under act of Congress of March 3, 1879.

Copyright, 1937, by the NEW ENGLAND WATER WORKS ASSOCIATION.

OFFICERS

OF THE

New England Water Works Association.

1936—1937.

PRESIDENT

HARRY U. FULLER, Engineer, Portland Water District, Portland, Me.

VICE-PRESIDENTS

WARREN J. SCOTT, Director, Bureau of Sanitary Engineering, Connecticut State Department of Health, Hartford, Conn.
(Term expires September, 1937)

GEORGE A. SAMPSON, of Weston and Sampson, Consulting Engineers, Boston, Mass.
(Term expires September, 1938)

DIRECTORS

PERCY A. SHAW, Superintendent and Engineer, Water Works, Manchester, N. H.
(Term expires September, 1937)

HAROLD K. BARROWS, Consulting Engineer, Boston, Mass.
(Term expires September, 1938)

FRANCIS H. KINGSBURY, Massachusetts State Department of Health, Boston, Mass.
(Term expires September, 1939)

PAST PRESIDENTS

(Members of Executive Committee)

HOWARD M. KING, Superintendent, Water Department, Springfield, Mass.

ROGER W. ESTY, Superintendent of Water Works, Danvers, Mass.

SECRETARY

FRANK J. GIFFORD, Dedham, Mass.

TREASURER

LELAND G. CARLTON, Water Registrar, Springfield, Mass.

EDITOR

GORDON M. FAIR, 112 Pierce Hall, Harvard University, Cambridge, Mass.

THE ASSOCIATION was organized in Boston, Mass., on June 21, 1882, with the object of providing its members with means of social intercourse and for the exchange of knowledge pertaining to the construction and management of water works. From an original membership of only TWENTY-SEVEN, its growth has prospered until now it includes the names of 800 men. Its membership is divided into six classes, viz.:

A Member shall be an officer or employee of a public or private water works, an engineer, chemist or other person qualified to aid or interested in the advancement of knowledge relative to water works.

An Honorary Member shall be a person of acknowledged eminence in some branch of water supply or of engineering.

A Life Member shall be a member whose service to the Association entitles him to special recognition by the Association.

A Junior shall be not less than eighteen years nor more than twenty-five years of age, a student or connected with water supply work.

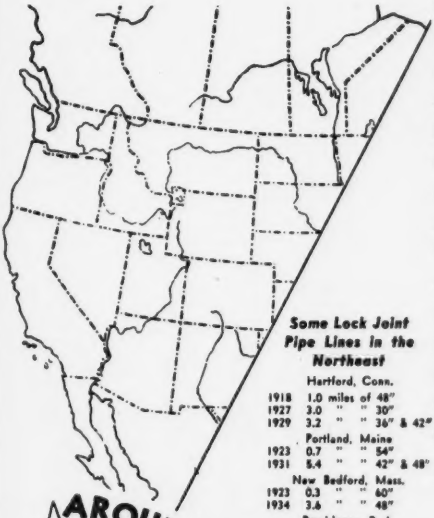
An Associate shall be either a person, firm or corporation engaged in manufacturing or furnishing materials or supplies for the construction or maintenance of water works.

A Corporate Member shall be either a Water Board, Commission, Company or Municipal Corporation.

The initiation fees and annual dues are as follows:

	Initiation Fees		*Annual Dues*
Members	$ 3.00	Members	$ 6.00
Juniors	1.00	Juniors	3.00
Associates	10.00	Associates	20.00
Corporate Members	10.00	Corporate Members	10.00

This Association has at least eight regular meetings each year, of which five are held in Boston, one in northern New England, one in southern New England, and one, the annual convention, held in September on such date as the Executive Committee may designate.



Some Lock Joint Pipe Lines in the Northeast

Hartford, Conn.
1918 1.0 miles of 48"
1927 3.0 " " 30"
1929 3.2 " " 36" & 42"

Portland, Maine
1923 0.7 " " 54"
1931 5.4 " " 42" & 48"

New Bedford, Mass.
1923 0.3 " " 60"
1934 3.6 " " 48"

Providence, R. I.
1926 6.8 " " 48" & 60"

Boston, Mass.
1927 1.7 " " 30"

WATER supplies throughout the Northeast section of this country generally have highly tuberculating and corrosive characteristics. Yet in the many installations of Lock Joint Concrete Pressure Pipe within this area, there is no indication whatsoever of any tuberculation, or corrosion of the steel structure of the pipe. The substantial walls of rich, dense concrete, in which all the steel is embedded, have proven their ability to permanently protect the steel. There is no loss of High Carrying Capacity and no loss of Strength with Lock Joint Concrete Pressure Pipe.

AROUND THE COMPASS WITH LOCK JOINT PIPE

NE E SE S

"EVERY JOINT AN EXPANSION JOINT"

In the North-East

LOCK JOINT *Reinforced Concrete* PRESSURE PIPE

SEWER
CULVERT
PRESSURE
SUBAQUEOUS

LOCK JOINT
PIPE COMPANY
Established 1905
AMPERE, NEW JERSEY

HOTEL PENNSYLVANIA

THE STATLER HOTEL

IN NEW YORK CITY

Official Convention Headquarters

for the

NEW ENGLAND WATER WORKS ASSOCIATION

Big ones at CINCINNATI!

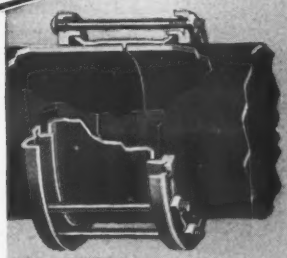
ON LINES OF EVERY SIZE!
Lines of all diameters are being Dresser-coupled in cities like these
Danville, Ky. Ironwood, Mich.
Ferndale, Wash. New Brunswick, N.J.
Fort Smith, Ark. Ponca City, Okla.

As great in diameter as a six-foot man is tall, are these Cincinnati twin raw-water mains, constructed during 1936 at the water purification plant and joined with Dresser Couplings. A few years before, another Cincinnati water line (48″) was also Dresser-coupled.

FIVE REASONS WHY MODERN WATER LINES ARE DRESSER-COUPLED:

1. PERMANENT TIGHTNESS—proved for 50 years, on 150,000 miles of pipe.
2. FLEXIBILITY—normal pipe movements—present in every line—are absorbed.
3. SIMPLICITY—joint parts are "factory-made"; ordinary labor can install.
4. STRENGTH—predetermined; joints safely withstand any specified pressure.
5. TRUE ECONOMY—a truly lower joint cost throughout the life of the line.

Write for our General Catalog No. 36.



Cutaway view of Dresser Style 38 Coupling, showing working principle. Note that plain-end pipe is used. The resilient gaskets, flexing with the pipe, safely absorb pipe movements.

THE MODERN TREND IS TO DRESSER COUPLINGS

S. R. DRESSER MFG. COMPANY, BRADFORD, PA. • *In Canada:* Dresser Mfg. Company, Ltd., 60 Front St., W., Toronto, Ont.

Table of Contents

	PAGE
Size of Meters for Services. By Samuel H. MacKenzie	367
Meeting the Demand for Recreation Facilities near Public Water Supplies. By David E. Moulton	370
The Corrosion Problem in Cambridge, Mass. By M. C. Whipple	376
The Influence of Dissolved Oxygen in Accelerating the Corrosive Action of Water. By F. Wellington Gilcreas	380
Neutralization of Corrosive Action. By Robert Spurr Weston	384
Development and Use of Spun Bituminous Coating for Water Pipe in Great Britain. By J. Mitchell	390
Development and Use of Spun Bituminous Coatings for Water Pipe in the United States. By George E. Boyd	393
Qualifications of Operators of Water Treatment Plants. By Warren J. Scott	402
The Needham Gravel-packed Well. By Bayard F. Snow	409
Experiences with Low-velocity Gravel-packed Wells. By Paul F. Howard	424
Additional Ground Water Supply for Woburn, Mass. By John P. Wentworth	430
Some Operating Experiences with Iron Coagulants. By Malcolm Pirnie	437
Proceedings:	
Fifty-sixth Annual Convention	454
Address of Welcome	455
Award of Dexter Brackett Memorial Medal	457
Report of Tellers of Election	461
Presidential Address	461
Report of Secretary	466
Report of Treasurer	469
Report of Editor	473
Report of Finance Committee	475
Progress Report of the Committee on the Advisability of Water Departments Regulating Water Piping and Fixtures within Buildings	476
Obituaries:	
John Carroll Chase	480
Harrison Prescott Eddy	482

New England Water Works Association

ORGANIZED 1882.

Vol. LI. December, 1937. No. 4

This Association, as a body, is not responsible for the statements or opinions of any of its members

SIZE OF METERS FOR SERVICES.

BY SAMUEL H. MACKENZIE.*

[*Read April 29, 1937.*]

It almost seems as if this subject was old enough to have been settled and as if it needed no further consideration, but most of us have found out that this is a changing world. Truth never changes but our conception of it may need adjusting. So it is with meters. In the past, it was more or less a general practice in a good many places to determine the size of the meter required by the size of the pipe rather than by the consumption and size of draft. I believe it is now becoming more general practice to give the latter factors due consideration, but the problem is to determine what the peak load on any certain line is or may be.

We shall consider small or household meters first. The ordinary flow for household purposes is about as follows:

Fixture	Gallons Per Minute
One kitchen faucet	5
One toilet with tank	5
One bath tub	5
One lavatory	3
One garden hose with nozzle	7
One 50-ft. hose without nozzle	11

Tests that we made showed the following losses in pressure:

Rate of Flow, g.p.m.	Size of Meter, Inches	Loss, Lb. per Sq. In.
22	5/8	15
34	3/4	17
48	1	20

Fair requirements for domestic service are about as follows:

	Flow, g.p.m.
1-Family house	15
2-Family house	22
3-Family house	30

These quantities may be exceeded at times, but not often enough to overtax the meter.

*Water Department, Southington, Conn.

Taking these figures as a basis, I should say a ⅝-in. meter had ample capacity for a two-family house and a ¾-in. meter for 3 or possibly 4 families. If flush-valve toilets are used, it changes the picture, as one such toilet takes water at the rate of nearly 20 g.p.m. so that such a service would require a ¾-in. meter for both one family and two families. I believe it would be best to use a 1-in. meter for three- and four-family houses.

When considering meters for other uses than domestic purposes, a careful check-up should be made of possible openings and of the quantity that may be drawn. Here, the new Meter Master comes to mind, as with that instrument, the actual flow can be determined and guess work eliminated. It almost seems unnecessary to write a paper on how to determine the proper size of meters for services when it can so easily be determined, but of course, a certain amount of judgment has to be used in addition to the record furnished by the Meter Master.

When considering meters larger than those ordinarily required for dwellings, the service to be furnished needs even more careful consideration, as the variation in flow is liable to be large in range. I believe disc or piston meters are satisfactory on most services up to 1½-in. as they will record even the small flows quite accurately. We just made a test of an 1½-in. disc meter on a service where formerly we were using a 2-in. compound meter. We found that it was recording quite accurately at 1/32-in. flow which at our pressure is 0.3 g.p.m. It is also capable of taking care of the larger flows, which would indicate that the compound meter was not needed for that particular service. Where meters larger than 1½ in. are required, there is no question that most of us have used larger meters than necessary. I cannot speak in regard to disc meters of 2 in. and larger in size, but I have had experience with compound meters. I prefer the compound meter with the small meter as a separate unit.

We had a great deal of trouble with our first compound meters, where the two meters were in one unit. The small side was continually getting out of order and we had no way of testing it separately. With the separate unit, if the small side is changed frequently, trouble can be almost entirely eliminated. We have a 2-in. compound meter set on a 4-in. service and have found that our minimum flow under ordinary conditions as recorded by the small meter is 1¼ g.p.m. and the maximum flow 10 g.p.m. and as recorded by the large meter the minimum is 0 g.p.m. and the maximum 22½ g.p.m. From this record it would appear that a 1-in. meter would carry the service, but that a 1½-in. disc meter would be preferable. On account of water being required for flushing boilers occasionally, it seemed best, however, to install the 2-in. compound meter. We have a 4-in. compound meter in a 4-in. line which showed on test a minimum on the small side of 13 g.p.m. and a maximum of 20 to 30 g.p.m. and a minimum on the large side of 0 g.p.m. and a maximum of 62½ g.p.m. If we had known what I know now, I believe we would have set a meter not over 3 in. in size on this service.

In conclusion I would like to say that I have no interest in the making

or selling of Meter Masters or any like equipment, but that I believe it would be a good investment for any water company or department that has a goodly number of meters in its system over $\frac{5}{8}$ in. in size to make or have made a test of flows through the various meters for the purpose of determining the proper size of meter for each particular service.

MEETING THE DEMAND FOR RECREATION FACILITIES NEAR PUBLIC WATER SUPPLIES.

BY DAVID E. MOULTON.*

[*Read September 21, 1937.*]

The Portland Water District is now sponsoring a project, under the auspices of the Works Progress Administration, for the construction of a recreational area adjoining the water shed of Portland's water supply. It has been suggested that this somewhat novel method of protecting a water supply by enticing the population away therefrom might be of interest to the New England Water Works Association and the writer was invited to present a paper on the subject.

It has been difficult to confine the paper entirely to the present project and the result is more a history of the efforts of the Portland Water District to conserve and protect the wonderful water supply which nature provided in the Sebago Lake water shed. The lake is only sixteen miles from Portland and has an elevation of 270 ft. above mean tide in Portland Harbor. It has a water surface of about 46 sq. miles, and in many places is over 300 ft. in depth. Indeed, the water storage is so enormous that although the daily run-off from Presumpscot River is 400 m.g.d., it would require more than eight years to empty the lake even if no water ran in meanwhile. This tremendous natural storage is further augmented by 30 additional lakes and ponds tributary thereto, making a total water area of over 90 sq. miles and a water shed of about 400 sq. miles. The lake is pear shaped. Its principal inlet, the Songo River, enters the upper end of the Great Bay, so called, while the intake of the Portland Water District is at the extreme end of the Lower Bay, some 12 miles from the River. The Lower Bay is about 1½ miles in diameter. The outlet of the lake, Presumpscot River, is about 8 miles from the intake, and such current as the outlet develops, is away from the intake. The large extent of the water surface and the absence of current, coupled with extreme depth, provide a natural sedimentation basin, which for many years apparently served to care for all pollution that may have entered the lake, and no serious water-borne disease was ever traced to the water, even in the absence of inspection and protecting legislation.

The first problem that faced the District in 1907, when it undertook to acquire the properties of the water companies then supplying the City of Portland, was an examination of this source of supply, obviously adequate, but of which no proper sanitary survey had ever been made. The District was fortunate in having as its Consulting Engineers, Allen Hazen and George C. Whipple, under whose direction a complete sanitary survey

*Attorney, Water District, Portland, Me.

of the water shed was undertaken. It is a singular coincidence that the young man just out of college, selected to do this work, was no other than the distinguished engineer, George C. Bunker, who is the recipient for 1937 of the Dexter Brackett Memorial Medal. It is also worthy of note that the water companies in making a similar survey engaged James C. Caird, later to become as he now is, Consulting Engineer for the District.

The surveys disclosed the existence of 136 cottages, 12 camps, 3 summer schools and 1 hotel, all immediately upon the shores of the lake and mostly around the Lower Bay. Many of these cottages were provided with old-fashioned privies and sinks, located less than 200 ft. from the shore. An analysis of the water in the Lower Bay showed bacteria running from 50 to 100 per c.c. near the shore line and from 3 to 10 per c.c. in the center of the Bay. The colon bacillus was found in a considerable number of the samples. The effect of sedimentation was obvious, and the bacteria would practically disappear at one-half mile from the shore. The surveys established to the satisfaction of the engineers representing both the Water District and the Water Companies, that the water of Sebago Lake in its natural state had all the elements of an ideal water for domestic and sanitary purposes, and that with proper sanitary regulations, the water could be safely used without filtration. In his book, "The Value of Pure Water," George C. Whipple compared the waters of Sebago Lake with water that was then supplied to Boston, Mass., Cleveland, Ohio, Worcester, Mass., New York City, Jersey City, N. J., Springfield, Mass., Philadelphia, Pa. and St. Louis, Mo., stating that in his opinion the water in Sebago Lake was of the highest value of all from the standpoint of turbidity, odor and color. The engineers recommended unanimously, however, that the District acquire the shore line around the Lower Bay and remove the cottages therefrom; that further legislative protection be secured, and that a full time sanitary inspector be engaged to enforce the laws and regulations.

Our program then became one of protecting the water shed to insure safe water for the future. The general laws of Maine relative to the protection of public water supplies (Section 1, Chapter 129 of the Revised Statutes) only provided penalties for *knowingly* and *wilfully* corrupting the source of any water supply. Inasmuch as such pollution would ordinarily be done without any criminal intent, the general law, as a measure to safeguard the purity of the water supply was, and always will be for practical purposes, useless.

In addition to the General Laws, however, Chapter 94 of the Private and Special Laws of 1903, entitled "An Act to Prevent the Pollution of the Waters of Sebago Lake" gave a considerable measure of protection. This Act distinctly forbade the use of any structure on the shores of the Lake in a manner that would permit the sewage or drainage therefrom to enter the lake. The Supreme Court was given jurisdiction in equity to enjoin any violation of the provisions of the Act. By Chapter 188 of the Private and Special Laws of 1907, the Act was further amended by including direct tributaries of the lake, and by prohibiting the discharge of polluting matter

from the steamboats or other craft on the lake. This Act was of great assistance to the District. The steamboats and freighters on the lake constituted a serious hazard. All of them were discharging their waste matters directly into the lake and it was only after persistent activity of the District that this hazard was removed by the installation of Kaustine toilets. At first these were installed at the expense of the District. After their feasibility and efficiency was established, the owners of the craft were compelled to undertake the expense of their maintenance.

Legislation was also secured prohibiting bathing within two miles of the intake, and providing that no new structures should be erected within 200 ft. of the shore line without first submitting satisfactory plans for the discharge of drainage therefrom. Many cottages about the Lower Bay were purchased or condemned. The acquisition of property was followed by the erection of fences to prohibit access to the shore. The drainage from Sebago Lake Village was remedied by the construction of a sterilizing plant near the outlet of the brook where the drainage of the village is sterilized before the waters enter the lake. Other possible sources of pollution occasioned by spring freshets were covered by temporary sterilizing outfits.

At the present time more than 98 per cent. of the shore line within two miles of the intake is owned and controlled by the District, over $380,000 having been expended for that purpose. This acquisition of lands was indeed timely as there has been a continuing increase in the number of cottages and camps, the latest survey disclosing 528 cottages, 14 summer camps for boys and girls, 7 summer hotels, 5 stores and 2 public bathing beaches, all on the water front, but owing to the control of the lower bay, all more than two miles from the intake. As might well be expected these precautions have resulted in a gradual improvement in the waters of the lake.

At first, no attempt was made to treat the water, and it was delivered to consumers in its natural state. In 1903 under the direction of James C. Caird, a plant was installed for treating the water with hypochlorite, and this method was continued until 1920 when automatic chlorine machines were installed. Continuous automatic treatment of the water is now conducted at a point about one mile from the lake where the different supply lines leading to the city diverge from the mouth of the new conduit. Under ordinary conditions, about 1 lb. of chlorine per m.g. is required to completely sterilize the water. During the spring freshets and fall overturn of the waters, as high as 5 lb. per m.g. are found necessary.

At times, weather conditions increase the number of algæ to a point where larger chlorine doses are necessary. These algæ troubles are indeed trivial as compared with water supplies from shallow ponds, and have reached no proportion which causes alarm. The District, however, at the present time is conducting a series of experiments, hoping to remove the algæ at a small expense through the use of Magnetite filters which are being experimented with at the Chlorine Station.

Notwithstanding all of these precautions, the District has been put

to a great deal of annoyance by the unauthorized use of the water shed outside of the area purchased and controlled by the District. Very little trouble has been experienced with the permanent occupants and cottage owners, but Sebago Lake has long been famous as a summer resort, and there have always been itinerant campers and sojourners who, in spite of all precautions, have entered upon the protected water shed and overstayed their welcome. Temporary camps have been maintained without proper sanitary equipment. Bathing has been unrestricted, and the public use of the unprotected water shed offers a continual menace from these roving campers. The prohibition of bathing within the Lower Bay naturally deprived the local residents of this privilege which they had long enjoyed. For many years the Trustees of the District had sought to remedy this situation and prevent the continued menace of the campers along the shores.

The long-sought opportunity arrived a year ago when the New England Cities Ice Company abandoned the use of the Otter Ponds where they had been harvesting ice for many years, and the property was purchased by the District. These ponds, while very close to Sebago Lake, are below the level of the lake and entirely outside of the water shed that requires protection. When the Works Progress Administration announced itself ready to provide free labor for public works, the Trustees immediately suggested a project to develop the Otter Pond area with this assistance. The largest of the five ponds is about one-half mile in length, and the shores are well wooded. All are in a glacial morain with gravel and sandy subsoil, and but for the steepness of the banks would have natural sandy beaches. It was decided to move the sand and gravel adjoining these ponds into the ponds and create suitable bathing beaches.

Following the acquisition by the District of the old picnic grounds adjoining the Sebago Lake Railroad Station, the local authorities purchased a site for ball grounds near the Otter Pond location. This partially developed site was included in the recreational project, and the ball grounds with the assistance of W.P.A. labor have been graded, bleachers for public use constructed of split oak logs, set on posts on elevated earthen banks, making a well designed stadium with seating accommodations for several hundred spectators. Pine trees were brought in from the reforestation area of the District and the grounds surrounded and protected from public view by attractive hedges. Parking spaces were graded and graveled. Tennis courts have been laid out adjoining the ball grounds, also horseshoe pitching courts. Over five miles of roads and trails have been laid out, the growth removed and about one-half the mileage is already completely graded and graveled.

The recreational area has been divided in accordance with the various proposed uses. One part is set aside for day picnics and local parties. Here more than a dozen stone fire-places have been built which are daily in use, although the park is not yet formally opened to the general public. During the winter, thousands of yards of sand and gravel were deposited by trucks around the shore of the largest pond. Later this sand and gravel were sluiced into the pond by hose streams from an old fire engine. By these means the

steep banks have been levelled off and a shallow beach provided for bathing purposes. Adjoining the beach is a large parking area which has been cleared, and extensive picnic grounds have been constructed, the ground being cleared of underbrush wherever necessary, although leaving an extensive area for the conservation of wild life. Many acres of wooded ground overlooking the ponds have been made available for public use.

Trailer camps and overnight camp sites have been located a considerable distance from the local picnic grounds. The sites have been surveyed, and considerable preliminary work has been done, but the sites are not yet available for use.

The area is well adapted for winter sports, as the hills afford ample opportunity for skiing and tobogganning, and all of the ponds are available for skating, ice hockey and other winter sports. Although the project has been going on less than a year, already the Works Progress Administration has provided free labor to the amount of $40,000, while the District has furnished material and equipment to a value of about $4,000. If the free labor holds out, it is planned to complete the trailer camps and extend the trails to include the very interesting fishery pools which the state maintains at the outlet of the old conduit. This conduit is no longer in daily use but is maintained as an auxiliary supply in case of accident, and the daily run-off through the underground conduit is utilized to supply cold water for the fish pools where young salmon and trout are being raised. Plans have already been made for bath houses, an administration building and small camps or temporary shelters to be distributed over the area.

In prosecuting the work, valuable advice and assistance have been given by several of the governmental agencies, including the National Park Service, the Recreational Service, as well as the State Department of Public Parks. The final method of administration of the project when completed, however, is still in the air. It has been suggested that the area, when completed, be turned over to the State Park Department. This Department, however, is at present without sufficient funds to undertake the project, as it is hoped to be developed, the organization not being set up to care for administration except during the summer months. It is confidently expected that the winter use of the area may be considerable and may even approach the summer use. No other similar facilities are available in this the most thickly settled portion of the state. Another plan suggested is a local recreational corporation to be organized to undertake supervision of the grounds, charging nominal sums which in the aggregate would equal the cost of the service rendered. The project as originally designed to restore to local citizens their bathing and recreational facilities and to remove the temporary campers from the unprotected area has proved entirely satisfactory. Both of these objects have been accomplished. The more ambitious plans for developing the area for recreational purposes for their own value is most attractive, but in the judgment of the Trustees of the Water District, is beyond their province. The sanitary inspectors of the District, however, report with a great deal of satisfaction the assist-

ance already manifest in clearing the unprotected and undeveloped water shed from itinerant campers. Heretofore, our inspectors have been unable to direct these parties to other camping sites where they would not be trespassing.

The Otter Pond Park, therefore, even in this stage of its development may well be classified as of great assistance in protecting the water shed of our largest public water supply by these indirect and evidently efficient methods.

THE CORROSION PROBLEM IN CAMBRIDGE, MASS.

BY MELVILLE C. WHIPPLE.*

[*Read September 22, 1937.*]

The nature of this paper is largely historical in that it reviews rather briefly the corrosion problem in Cambridge as it has varied over a period of years. The changes in the severity of corrosion of water pipes in this time have been due principally to differences in the treatment of the municipal water supply. Accordingly, this treatment will be described as it has varied from time to time, and an attempt will be made to correlate it with the changing manifestations of corrosion.

Source and Character of the Water Supply. The public water supply of the city of Cambridge is obtained from impounding reservoirs situated a few miles north and west of the city. Coming from surface sources the water is soft, of moderately high color, has practically no turbidity, and contains a few parts per million of carbon dioxide. A typical analysis shows the following:

Hardness	28	p.p.m.
Alkalinity	15	p.p.m.
Color	40	p.p.m.
Carbon Dioxide	5	p.p.m.
pH value	6.7	

The supply is brought to the city by pipe line and conduit, where it is treated in a rapid sand plant by the following processes, coagulation with alum, filtration, chlorination and corrective treatment with lime for corrosive properties. When delivered to the consumers the water exhibits the following analysis:

Hardness	45	p.p.m.
Alkalinity	22	p.p.m.
Color	2	p.p.m.
Carbon Dioxide	0	p.p.m.
pH value	8.8	

Corrosion before the Adoption of Filtration. Before the advent of filtration, which came in April, 1923, corrosion was a problem in Cambridge, although not a severe one. Iron and steel pipes were found to have a fairly short life in plumbing systems. This was in spite of the protective action of organic deposits common to the water and in spite of the fairly high hardness. The supply appeared to be more corrosive than the analysis indicated. Even brass pipe was affected. It was not uncommon to see on

*Assistant Professor of Sanitary Chemistry, Harvard Graduate School of Engineering, Cambridge, Mass.

brass hot-water piping the white excrescences indicative of dezincification. At that time practically all the brass used in plumbing systems in the city was Muntz metal, 60 per cent. copper and 40 per cent. zinc. The action of the hot unfiltered water on brass pipe was not rapid but nevertheless was continuous and noticeable. Failures were recorded after a period of contact of 10 to 20 years. They were more common in installations employing high temperatures and active circulation, as those of apartment houses.

Filtration without Correction of Corrosive Quality. Following the adoption of filtration, water was delivered to the city for a period of six months without correction of corrosive quality. No provision had been made for such treatment in the original design of the plant. The experience of these first six months clearly indicated the need of corrective treatment. Wherever the water came in contact with iron, more particularly in hot-water systems, red water made its appearance. Plumbing fixtures were stained, and there was evidence that the action on brass piping was accelerated. As delivered to consumers, the water at this time showed the following characteristics:

Hardness	28	p.p.m.
Alkalinity	5	p.p.m.
Carbon Dioxide	7	p.p.m.
pH value	6.0	

Use of Soda Ash for Corrective Purposes. The first step undertaken to combat corrosion by the filtered water was the addition of soda ash to the effluent. This was begun in November, 1923, and continued until March, 1930. Enough soda ash was added at first to maintain an average CO_2 content of 4 p.p.m. As time progressed and corrosion persisted the CO_2 content was finally reduced to an average value of 1.5 p.p.m. During the last year of this treatment the water as delivered showed the following average values:

Hardness	28	p.p.m.
Alkalinity	19	p.p.m.
Carbon Dioxide	1.5	p.p.m.
pH value	7.0	

Although the use of soda ash reduced the severity of corrosion, as judged from outward signs such as the partial abatement of red water, it was evident from accumulated experiences during the period of its use that such treatment was not doing a satisfactory job.

Most of the brass pipe in service throughout the city at this time was 60-40 in composition. It showed continuous deterioration, and failures were numerous, necessitating the renewal of house systems in many cases. Illustrating the rapid rate of corrosion was the experience in one of the dormitories of Harvard University. Here an installation of 60-40 brass pipe showed pronounced dezincification with failure in hot-water service after

a period of three years. All the evidence pointed at this time to the conclusion that 60-40 brass would not withstand the action of Cambridge water.

It was during this period that much was heard of the resistant qualities of 67-33 brass. The author installed pipe of this composition in a new house in Cambridge in 1925. Five years later, examination of this pipe in hot-water service showed excrescences at the threads and warts or tubercles on the inside together with copper "plugs" where dezincification had occurred. The pipe had not yet failed in service but was disappointing in its resistance to corrosion, or to state the point in another way, Cambridge water was disappointing in the intensity of its corrosive action. Similar experience with 67-33 brass pipe was reported from Harvard University, where three years of service in hot-water lines gave evidence of rapid deterioration. Brass pipe in cold-water lines exhibited a less intensive action.

In November, 1929, a committee of some 12 interested persons met to discuss the question of suitable pipe composition for new buildings at Harvard University. A large amount of evidence was presented to show that 60-40 and 67-33 brass pipe in hot-water lines in the University were both subject to rather severe action. Also it was shown that red brass, 85-15 in composition, was subject to some corrosion with pitting, over a period of three years. The outcome of this conference was that copper pipe was finally adopted for the buildings.

Part of the evidence laid before this conference came from a long-time experiment made by the Department of Sanitary Engineering, Harvard University at the Cambridge Water Purification Works.* As a part of this experiment copper, red brass, and admiralty metal were exposed to the action of hot city water in a battery of parallel pipes 100 ft. long. The period was from April, 1927, to November, 1929, which corresponded with the use of soda ash in increasing amounts. At the conclusion of the experiment it was found that the copper pipe exhibited only slight surface action with no pitting; that the red brass showed slight surface action without pitting; that the admiralty metal showed considerable surface action with marked dezincification and scattered pits. A long feed line of 67-33 brass that led to this experiment exhibited pronounced action with warts and dezincification.

Corrosion with Lime Treatment. All this experience, accumulated during the time soda ash was applied as a corrective, convinced those responsible for the operation of the purification works that a different form of corrective treatment was necessary. The chief reason for using soda ash had been that it did not increase the hardness of the water, which was already higher than that of many surrounding communities. Believing that water consumers would prefer a higher hardness and slightly increased soap bills to the inconvenience and expense of plumbing renewals, corrective treatment was accordingly carried farther with lime and at a considerably reduced

* This JOURNAL, 44, 499 (1930).

cost. Beginning in March, 1930, lime was added to the final effluent in gradually increasing amounts until 1934. Since that time, enough has been used to saturate the water with $CaCO_3$ and to give a pH value of approximately 8.8.

We may now turn to the manifestation of corrosion with this most recent treatment. Cold-water lines of iron or steel which have been observed have shown a discharge of distinctly less rust and iron compounds and have produced less staining of plumbing fixtures. Observations are lacking as to their tendency to pit and form tubercles. Most of such lines are old and were corroded in service before lime was applied to the water. There has been less complaint on the part of plumbers and householders as to corrosion and as to failures in service. This applies to both iron and brass pipe.

In April, 1930, test pieces of various kinds of brass and of copper pipe were placed in the hot and cold-water lines of the author's house in Cambridge. The installation was made by the Chase Brass and Copper Company of Waterbury, Conn. The samples were allowed to stay in place for five years and were then removed for examination with the following findings:

1. Copper, red brass (85-15), admiralty metal (70-29 and 1 per cent. tin), and Alpha brass (66-33 and 0.5 per cent. lead) all were in excellent condition and showed very little evidence of corrosion.

2. Tin-bearing Alpha brass (66-33 and 0.75 per cent. tin) taken from the hot-water line showed plugs of dezincification extending one-quarter to one-half the distance through the pipe wall. This alloy resisted the cold water.

3. Muntz metal (60-40) showed plugs of dezincification extending somewhat less than half way through the wall in the case of the cold-water line and somewhat more than half way in the case of the hot-water line.

During the time these tests were going on, the city water was treated with lime but not to the point of saturation with calcium carbonate as has been the case since 1934. There was no CO_2 present and an average pH value of 8.4 was maintained. In view of the findings of the tests which were made under these previous conditions and in view of the lessening frequency of failures of pipe due to corrosion it is my belief that with the present complete treatment of the water there is a minimum of corrosion and that all the brass alloys in common use, with the possible exception of Muntz metal, together with copper are subject to no more than mild action.

Tests made over a considerable period of time with copper pipes seem to indicate that this metal is best suited to service with Cambridge water.

THE INFLUENCE OF DISSOLVED OXYGEN IN ACCELERATING THE CORROSIVE ACTION OF WATER.

BY F. WELLINGTON GILCREAS.*

[*Read September 22, 1937.*]

The accepted electro-chemical theory has established the significance of dissolved oxygen in controlling the rate, and to a certain degree the extent, of aqueous corrosion of ferrous metals and also of the non-ferrous metals frequently used in service pipes. Velocity of flow, temperature, concentration of dissolved carbon dioxide, and hydrogen-ion concentration are also factors of significance in any consideration of the solvent action of water on metals. Alkaline conditions, with resulting low hydrogen-ion concentration, retard corrosion. Dissolved solids also provide an inhibiting medium, particularly calcium carbonate, which, under definite conditions of concentration and pH value may precipitate to form a protective coating over the surface of the metal. Langelier's recent work† discusses the chemical relationships involved in the corrosive action of water and in particular the conditions under which calcium salts form protective coatings. He has developed a "saturation index" which is of use primarily in controlling anti-corrosion treatment and which at the same time is a very useful index of the potential corrosive action of the water.

The ground waters of Long Island provide excellent conditions for investigation of the effect of dissolved oxygen in the corrosive action of water, and a comparative study has been made of three typical public supplies. On the principle that carbon dioxide is the controlling agent in corrosion, a theory now discarded, two of these supplies are aërated to reduce the concentration of this dissolved gas in an endeavor to eliminate the sporadic occurrence of "red water."

In Freeport, water is secured from four Layne wells, 500 ft. deep. Water is pumped to an elevated tank where it is aërated through a fall of 18 ft.; it then flows by gravity, and without further treatment, to the distribution system. Complaints regarding the corrosive action of this supply have been limited almost entirely to the spring and fall seasons.

Results of analysis of the water are given in Table 1. These show the water as taken from the well to be very soft, with a low pH value, 5.2; free from dissolved oxygen and containing 30 p.p.m. of carbon dioxide. Aëration reduces the carbon dioxide to 15 p.p.m. The saturation index computed by Langelier's method is very low (—4.6) an indication of potentially serious corrosion. It is interesting to note that the raw water contained 0.4 p.p.m. of iron as drawn from the well, but aëration and storage in the elevated tank

*Division of Laboratories and Research, New York State Department of Health, Albany.

†Jour. A.W.W.A. **28**, 1500 (1936).

TABLE 1.— ANALYSIS OF FREEPORT WATER SUPPLY.

Source of Sample.	Temperature, °C.	Dissolved Oxygen, p.p.m.	Carbon Dioxide, p.p.m.	pH.	Alkalinity, p.p.m.	Hardness, p.p.m.	Iron, p.p.m.	Copper, p.p.m.	Zinc, p.p.m.	Saturation Index.
Layne Wells	15	0.0	30	5.2	6.0	14.0	0.4	...	...	...
Aërator Effluent	15	5.5	15	5.3	6.0	8.0	0.1	...	...	−4.6
Tap, Distribution System	16	5.0	11	5.3	5.0	8.0	<.03	...	...	...
Tap, Copper Pipe, Standing Conditions	...	...	...	6.3	10	16	<.03	4.2	...	...
Tap, Galvanized Pipe, Standing Conditions	...	...	...	7.1	15*	22*	0.26	...	10	...

*Includes effect of zinc salts.

TABLE 2.— ANALYSIS OF WILLISTON PARK WATER SUPPLY.

Source of Sample.	Temperature, °C.	Dissolved Oxygen, p.p.m.	Carbon Dioxide, p.p.m.	pH.	Alkalinity, p.p.m.	Hardness, p.p.m.	Iron, p.p.m.	Saturation Index.
Layne Wells	15	0.0	19.0	5.7	11.0	34	<.03	...
Aërator Effluent	15	9.0	6.0	6.4	13.0	28	<.03	−3.7
Tap Distribution System	21	9.0	6.0	6.4	18.0	28	<.03	...
Tap Distribution System Standing Conditions	...	...	...	6.3	14.0	...	<.03	...

reduced this to 0.1 p.p.m. Samples collected from a tap in the distribution system indicate a further substantial decrease in the iron content.

Inspection of a section of a main removed after service of one year showed the presence of tubercles 1/64 in. to 1/16 in. in diameter and the inner surface of the pipe to be almost completely coated with a thin rust deposit.

The supply at Williston Park is also obtained from two Layne wells, one 250 ft. in depth and the other 400 ft. As with the Freeport supply, water is pumped to an elevated tank, and aërated. It then flows by gravity through the distribution system. The results of the laboratory examination of this water are given in Table 2 and again indicate a water very soft, free

from appreciable quantities of iron, devoid of oxygen, with a carbon dioxide concentration of 19 p.p.m. and a pH value of 5.7. The saturation index is again low (— 3.7). Aëration reduces the carbon dioxide concentration to 6 p.p.m. with a consequent increase in the pH value to 6.4 and produces a dissolved oxygen concentration of 9 p.p.m. Samples collected from the distribution system under conditions of flow and standing over night reveal but little change in the composition of the water and no serious corrosive action; in neither case were appreciable quantities of iron found.

There have been no complaints recorded of "red water" or the rapid destruction of service pipes with this supply. Toilet fixtures observed in a fire station were not stained with rust, nor were there any other indications of active corrosion. No section of mains removed after long use was available for inspection, but the superintendent of the supply stated that when such sections are removed the inner surface is usually coated with a thin rust deposit but with no tubercles and no indication of deterioration in the metal.

TABLE 3.— ANALYSIS OF WEST HEMPSTEAD-HEMPSTEAD GARDENS WATER SUPPLY.

Source of Sample.	Temperature, °C.	Dissolved Oxygen, p.p.m.	Carbon Dioxide, p.p.m.	pH.	Alkalinity, p.p.m.	Hardness, p.p.m.	Iron, p.p.m.	Copper, p.p.m.	Saturation Index.
Layne Wells	16	0.3	26.0	5.1	7.0	20.0	<.03	...	−4.7
Tap Distribution System	24	0.0	24.0	5.1	6.0	36.0	<.03	...	...
Tap Copper Pipe Standing Conditions	...	...	...	4.8	1.0	...	...	1.1	...

The West Hempstead-Hempstead Gardens water supply is likewise secured from two Layne wells, 190 ft. deep and is pumped directly to the distribution system. Results of the examination of this supply are recorded in Table 3. The water is similar to that from the other two supplies, very soft with a low (0.3 p.p.m.) dissolved oxygen content, 26 p.p.m. of carbon dioxide and a correspondingly low pH value of 5.1. A negligible amount of iron is present in the water as drawn from the well. A sample from the distribution system showed no increase in iron content. The Langelier saturation index was —4.7, again suggestive of serious corrosion in the presence of a sufficient concentration of dissolved oxygen.

There have been no complaints of corrosion from this supply except in over-heated hot water tanks. Sections of old mains which had been in use for at least 10 years showed a definite rust scale with few, very small tubercles on the surface of the metal.

With all these supplies, no serious "red water" or similar unsatisfactory conditions in dead ends were reported, indicating that prolonged contact

with the metal fails to produce more extensive corrosion than that indicated by the tap samples examined.

Since brass and copper services are only infrequently used in this area, there is but little available information regarding the possible effect of these waters on non-ferrous metals. With the Freeport and West Hempstead supplies, however, it was possible to obtain samples of water representing conditions of standing overnight in both copper and galvanized pipe. With the unaërated West Hempstead water but little action in the copper pipe was found. At Freeport, however, where the concentration of dissolved oxygen is high, serious solvent action on copper pipe and on zinc from galvanized pipe was detected.

In view of the accepted theories regarding the influence of dissolved oxygen on the corrosive action of water, the results of this study are rather anomalous, particularly as they are concerned with ferrous metals. Analysis of the aërated Freeport and Williston Park waters indicates probable serious corrosive action in mains and service pipes. Examination of tap samples, however, and inspection of mains and plumbing fixtures show that corrosion is not at all serious and that except for tuberculation of mains in Freeport there is but little difference in the action of these two supplies and that of West Hempstead, in which dissolved oxygen is absent.

It is possible that a fine layer of ferric oxide, deposited under a particular condition of velocity of flow and composition of the water, may act as a protective coating and thus prevent further solvent action of these soft waters even in the presence of excess dissolved oxygen. Variations in rate of flow and changing temperature may slough off this coating and thus account for the seasonal complaints of "red water" in the Freeport supply. The absence of such a protective coating in service pipes of non-ferrous metals would, according to this hypothesis, expose them to the serious corrosive action shown on investigation.

It may also be that some other explanation, more in accord with present accepted theories, will account for the peculiar conditions existing in the Long Island water supplies. Further study of these and similar conditions seems essential to our knowledge of the corrosive action of water toward metals and especially of the influence of dissolved oxygen in accelerating such action.

NEUTRALIZATION OF CORROSIVE ACTION.

BY ROBERT SPURR WESTON.*

[*Read September 22, 1937.*]

It is well known that pure water and most natural waters, particularly those within the region represented by many members of this Association, attack metals appreciably. If they do not, it is because of pipe linings, protective films deposited from the water, or chemical treatment.

Those waters which are most aggressive in their action are high in carbon dioxide and low in protective organic and inorganic contents. Furthermore, the presence of oxygen is a factor in the formation of rust following corrosion and in maintaining the corrosion cycle in the presence of even a small amount of carbon dioxide. The pH value, which is a measure of the hydrogen ion concentration in the water, is also important. Therefore, the aim of treatment is to remove the excesses and supply the deficiencies.†

If one builds a new house containing either steel, wrought iron, galvanized wrought iron, brass or copper piping and turns on the water, whether that of Portland, Nashua or Boston, iron will be dissolved from steel and wrought iron, zinc from galvanized iron and brass, and copper from copper. If one should turn on pure Poland Springs water, he would probably get nearly the greatest corrosive action that a natural water can produce.

After a while some of these waters will deposit a thin protective film of organic matter, a few will deposit a mixture of iron rust and chalk, while many will go on corroding until filled and stopped. Treatment for overcoming this condition varies from corrective to protective, each water presenting its own problem.

Aëration. Some waters, high in carbon dioxide, may be aërated to advantage; on the other hand, oxygen, a factor in the corrosion cycle, is introduced by aëration. However, all surface waters and most ground waters, even those free from oxygen in their natural condition, contain oxygen when delivered to the mains. This may be due to natural occurrence or introduction through leaky well tubes, suction mains, packing rings or open wells; so, in practice, one usually has to consider the treatment of a more or less oxidated water and one more or less aggressive.

Alkalies. When the pH value is too low, alkalies, like soda and lime, may be added to raise it, thus reducing the number of aggressive hydrogen ions in solution. While soda, usually added in its cheapest form of sodium

*Of Weston & Sampson, Consulting Engineers, Boston, Mass.

†Abel Wolman, "Controlling Corrosion" *Jour. A. W. W. Assn.*, 25, 947 (1933).

carbonate or soda ash, will raise the pH value, it is less useful in the formation of films than is lime, the latter applied either as quick lime or hydrated lime.

The theoretical amount of lime to be added depends upon the chemical balance. The best amount to add depends upon practical considerations. Perhaps the best guide to treatment is to determine the chemical balance with reference to calcium carbonate (chalk). This is because calcium carbonate is usually the most prevalent alkali in water. Calcium carbonate is soluble to the extent of 25 to 30 p.p.m. in pure water; in water containing carbon dioxide, to many times these amounts.

To carry out the calcium-carbonate chemical balance or stability test, one determines the alkalinity of a portion of the sample; then to an equal volume one adds pure calcium carbonate in the form of precipitated chalk, stirs the mixture, settles, filters and determines the alkalinity in the filtrate. If the results show a greater alkalinity in the treated sample than in the untreated, the water is under-saturated; if less, over-saturated; if the same, the calcium carbonate is at equilibrium.

The amount of carbon dioxide in chemical equilibrium is expressed in the terms of the physical chemists by the following formula;

$$CO_2 \text{ (Associated)} = (Ca'').\ (CO_2' \text{ Combined})^2.k.$$

The most common way of restoring the chemical balance is by the addition of lime. With automatic dry feeders and with pH kits to guide one, this is much easier than formerly, and in the larger and well-attended works the problem is relatively simple.

However, even with perfect control of additions of lime, it is possible to maintain equilibrium with it for only one temperature. If the temperature be raised after treatment, as in a hot water boiler, the solubility of calcium carbonate will be increased, carbon dioxide liberated and corrosion begun; if decreased, as in a long distribution system in winter, the solubility of the calcium carbonate will be decreased and deposits will occur in pipes and meters.

So, in practice, one steers between these extremes by under-dosing or other expedients. One of these latter is to alternate relatively long lime additions with short additions of sodium silicate (water glass). Ordinarily, this forms a more insoluble coating in soft waters than can be produced by lime alone, and a more permanent one than formed by the silicate alone. This silicate-lime coating offers more resistance to the formation of tubercles than does the addition of lime alone. While lime usually gives the best effect, it has the disadvantage of increasing the hardness. On the other hand its cost is less than one-fifth of that of soda-ash for the same degree of neutralization.

Control of corrosion is best accomplished by the addition of enough alkali to maintain a desired pH value. It is possible to do so automatically by using a potentiometer with its electrode immersed in the treated water. This instrument not only records the pH value but, through relays, controls

the dosing devices. A Leeds and Northrup apparatus of this type has been in use for about five years for treating the Wanaque, N. J. supply. It now maintains the pH value of the delivered water at about 8.6.

The usual arrangement is to have dry feeders deliver the lime to mixing tanks from which milk-of-lime is pumped either through a special valve, controlled by a reversible motor, or through a special feeder employing a variable weir, likewise controlled. The valve or weir discharges more or less of the chemical to the water to be treated according to the setting on the pH recorder. While these apparatus are efficient and have been greatly simplified and improved, they are fine instruments, are costly and require rather more supervision than the ordinary devices for treating water.

Sodium Silicate. Hot water systems are most difficult to keep in condition, largely because of the carbon dioxide liberated at high temperatures.* Here, sodium silicate is useful, also sodium carbonate or hydrate, which neutralize with no danger of forming scale and with no increase in hardness. The reaction of sodium silicate in very dilute solutions is various and extremely complicated. Where waters contain little or no calcium, but considerable carbon dioxide, there is no precipitation in concentrations up to 0.10 per cent. In effect, it forms a gel upon the surface of the metal which is constantly changing into crystalline silica. The latter sloughs away, gives little protection and is being constantly replaced by newly formed protective gel derived from the applied silicate. Where calcium is present in considerable amounts and the pH value is fairly high, calcium silicate is formed which is quite insoluble under many conditions. While one usually thinks of silica as an insoluble substance, yet there is good evidence that natural water in distribution systems often absorbs or disperses it, sometimes re-depositing it elsewhere in either amorphous or crystalline form.

At Milford, Mass., where lime was applied for a long time for the protection of lead services, its addition was discontinued and replaced by sodium silicate. The good results following the use of fairly large doses of this chemical led to so optimistically great reductions in doses that corrosion re-appeared, and lime was again applied. Strangely enough, the alternation of the chemicals gave better protection than use of lime alone. At Winchester, Mass., the application of silicate for short periods alternates the application of lime for longer ones, with good results.

Ammonia-Chlorine. Mention must be made of the addition of chlorine with ammonia not only for removing *Crenothrix* and other similar organisms whose growth obstructs pipe lines, but also as a corrective of corrosion. H. S. Hutton† has reported the effect of these additions at Utica, New York, where, following the applicating of chlorine and ammonia, the carrying

*J. Tillmans, P. Hirsch and W. R. Hackmann, "Der Einfluss von höheren Temperaturen und Salzsäten auf das Kalk-Kohlensäure Gleichgewicht"; Das Gas und Wasserfach, **74**, 1 (1931).

†Protection of Distribution Systems by Correction of Water Quality, *Jour. A.W.W.A.* **29**, 237 (1937).

capacity of the pipe lines has been maintained at the required level while it lost previously as much as 20 per cent. in a period of six months. Similar improvements have been noticed at Rochester and other places.

Marble. Where supervision is negligible or absent, and the simpler chemical tests unavailable, the problem of neutralization is difficult. Until recently, the best expedients have been to pass the water through marble sand,*† or dose it with solid sodium silicate, using for the latter a solution tank on a by-pass like those used with small pressure filters. Sometimes Magnesite sand has been used in this way, but its effect upon the water is bad for many industrial processes.

Magno-doublesalt. This need for a better contact medium and, if possible, an automatic neutralizer, has led to the discovery by two men — Tillmans and Ritschel‡§, — at the same time, of a new material called Magno-doublesalt (Magno-doppelsalz). This is not much different from Magnesite ($MgCO_3$) in its action but far different in its effect. Magno-doublesalt is made by roasting Dolomite, driving the carbon dioxide off from the magnesium but leaving it in combination with the calcium as follows:

$$\begin{matrix} MgCO_3 \\ CaCO_3 \\ \text{(Dolomite)} \end{matrix} + \text{Heat} = \begin{matrix} MgO \\ CaCO_3 \\ \text{(“Magno-mass”)} \end{matrix} + CO_2$$

The new material and its action, also its application in practice, were described by August F. Meyer,** Director of the Berlin-Charlottenburg Water Works, in an article of much interest.††

The re-action to the new material with water containing carbon dioxide is as follows:

$$(1)\ MgO + H_2O + 2CO_2 = Mg(HCO_3)_2$$
$$(2)\ CaCO_3 + H_2O + CO_2 = Ca(HCO_3)_2$$

It will be noted that one atom of magnesium in the double-salt combines with 2 molecules of CO_2 whereas one atom of calcium combines with only one molecule of CO_2.

According to Director Meyer, the Magno-Verbund-Mass, or double-salt, may be used in an ordinary rapid filter of the gravity or pressure type, care being taken to provide a volume of material sufficient for all requirements. As the filter material is consumed in neutralizing the water, it must be replenished as required. When the grains are reduced in size, their hydraulic value is, of course, accordingly reduced and they are then removed during washing.

*"The Removal of Aggressive Carbon Dioxide by Contact Beds of Limestone or Marble." C. R. Cox, *J. Am. W. W. Assn.*, **25**, 1505 (1933).
†J. Tillmans, Vom Wasser. **6**, 59–91 (1932).
‡J. Tillmans, P. Hirsch und H. Lürmann "Neue Wasserentsäurungs Verfahren, Das Gas u. Wasser. **74**, 48–52 (1931).
§H. Haupt, Erfahrungen auf Entsäurungsanlagen, Das Gas u. Wasser, **76**, 47 (1933).
Neutralization, Deferrization und Demanganization Chem. Zeitung **73, 742–745 (1936).
††Also in his book "Trinkwasser aus Tahlsperren" (1937).

The new magno-filter is often used for protecting hot water systems. It is placed near the heater, the heated water being circulated through it. In this way, the proper equilibrium is established, while the particles of iron rust and chalk precipitated by heat in the system feeding the filter are retained therein and kept out of pipes and boilers. Likewise, when the water is cooled, the excess of free carbon dioxide which attacks lime is soon re-combined with the magno-double-salt in the filter so that corrosion is corrected. Just as at Sewickly (Pa.) where Chester* and his associates have used zeolite in gravity rapid filters for softening waters in combination with treatment for appearance, so may this new material be used for deferrization and demanganization in combination with neutralization, taking care to provide adequate filter areas for these purposes, as well as adequate volumes for neutralization.

The required amount of magno-double-salt for treatment varies, soft waters free from iron and manganese requiring only small amounts compared with hard waters in need of simultaneous deferrization and demanganization. Ordinary provisions are from 7 000 to 9 000 lb. of filter material per million gallons daily of capacity. Use of the material involves a loss of about 10.8 lb. per m.g. for each part per million of carbon dioxide. For example, an ordinary water containing 20 p.p.m. of carbon dioxide will consume 216 lb. of double-salt per million gallons; with the same content of carbon dioxide, one pound of Magno-mass can neutralize 5 545 gal. of water coincident with the formation of a protective coating on the pipe system. There is an increase in hardness due to an increase of calcium and magnesium carbonates. This increase would amount to 35 p.p.m. when neutralizing 20 p.p.m of carbon dioxide.

One great advantage of the new treatment is that protection is carried to the dead ends of the distribution system, a condition difficult to effect by dosage with lime. Director Meyer reports the success of the treatment in a variety of large and small works and gives some results from practice. The following from a high-service station in a Saxon industrial town is typical:

	Parts per Million.	
Determination.	Raw Water.	Filtrate.
Free carbon dioxide.....	25 to 31	None
Iron.....	0.5 to 1.1	None
Manganese.....	0.4	None or Trace

The Prussian Institute ("Landesanstalt") for Water, Soil and Air Hygiene, has approved the method of treatment, and a thorough study of the increase in carbonate hardness due to magno-filtration has been made by the Agricultural Experiment Station in the Kassel District in Germany. The latter experimented with a water which averaged a carbon dioxide content of 45 p.p.m. and a carbonate hardness which during 63 days averaged 85.6 p.p.m. Results showed the complete removal of carbon dioxide and an average increase in hardness of 31.6 p.p.m., raising the hardness of

*Zeolite Softening Plant Operating Experiences. J. T. Campbell and D. E. Davis, *Jour. A.W.W. Assn.* 22, 952 (1930).

the water to from 100 to 121 p.p.m. A phenolphthalein alkalinity of between 2 and 3.4 p.p.m. was maintained.

It is apparent that each supply presents its own particular problem. In one place, the use of sodium carbonate, or even of sodium hydrate, may be warranted; in another place, the additional cost of these chemicals is not counter-balanced by savings in soap and in repairs due to the formation of scale. Likewise must the use of the more expensive sodium silicate be judged. The new Magno material is not yet exported to this country, but the makers have announced their intention of producing it here. They quote its price at 112.5 R.M. for a ton (2 200 lb.) which would make the cost of material for treating a water containing 20 p.p.m. of carbon dioxide about $5.00 per. m.g. in Germany at the present rates of exchange. For neutralizing 20 per. p.m. with soda-ash and hydrated lime, the costs would be about $8.20 and $2.95 per. m.g., at current price respectively.

DEVELOPMENT AND USE OF SPUN BITUMINOUS COATING FOR WATER PIPE IN GREAT BRITAIN.

BY J. MITCHELL.*

[*Read September 22, 1937.*]

It has long been realised that, if water engineers are to avail themselves of the relatively cheap material which steel places at their disposal for pipes and similar articles, they must accept the necessity for adequate protection against corrosion. At one time, the pipe was merely dipped in a coal tar bath and externally wrapped with hessian or burlap. Experience soon showed that, for many reasons, this coating was not impervious to water and to other corrosive influences, and attempts were made to improve the standard of protection. This has been done in several directions.

Recognizing the need for consistency in the properties of the protective material and also the desirability of resisting unfavorable influences as regards temperature, pipe manufacturers have adopted blown petroleum asphalt in preference to coal tar. It is possible, with this material, to get a much wider range of suitable physical characteristics and increased longevity in service. Even with petroleum asphalt, however, it became apparent that there were many conditions of service where the relatively thin coating applied by dipping was not adequate to meet the prevailing conditions.

Assuming that the bituminous material had the necessary resistance to the corrosive element, the obvious course was to increase thickness of covering. This proved a matter of considerable difficulty, but ultimately the various difficulties were overcome and the coating which is known today as "Spun Bituminous Coating" was evolved. In 1925, British manufacturers placed this coating on the market. The protective material used was blown petroleum asphalt loaded with a suitable mineral filler. The object of the filler was to give the increased resistance to temperature influences which became necessary in order that relatively thick layers of material should remain *in situ* on the pipe under varying temperature conditions.

The problem, however, was not merely one of applying a thicker coating and of making it resistant to flow at prevailing temperatures. It also became necessary to ensure that the adhesion of the coating to the pipe surface was thoroughly good. In order to do this, various problems in technique had to be worked out and, as a result of the experience of over 10 years, it has come to be accepted today that two surface conditions of the steel, before the application of the coating, are essential to success:

*Director of Research and Technical Development, Stewarts and Lloyds Limited, Great Britain.

(1). The coating should be free from all mill scale, *i.e.*, coating must be applied to a bare *metallic* surface.

(2). The surface, in view of the viscosity characteristics of the bituminous mixture, must be warm in order that the bituminous material shall *wet* the surface properly.

When these conditions are met, it is possible to get a joint between the steel and the metal with a pulling strength of approximately 500 lb. per sq. in. at the interface. As this is about three times greater than the tensile strength of the bituminous mixture itself, it will be understood that the problem of adhesion has been completely solved.

The technique of the actual lining process is relatively simple. The pipe is descaled and warmed and, as a further insurance that the surface will be properly wetted by the bituminous mixture, it is given a preliminary dipping: it is then mounted on a machine with variable speed ratios to give the required centrifugal speed for any diameter. The molten bitumen in which the mineral filler has been previously incorporated in specially designed mixers is then introduced in sufficient quantity to give the required thickness. This is of the order of 3/16 to ¼ in., depending on the pipe diameter. The pipe is slowly rotated in order to spread the bituminous mixture evenly over the surface, and the speed is then stepped up to the required rate in order to finish the lining process. This takes about one minute. Whilst still spinning, the pipe is flooded from water sprays in order to chill the lining. The pipe is then ready for service.

Very short experience of pipe prepared in this way indicates the tremendous advantages as regards corrosion resistance which this type of protection affords.

Incidentally, many other advantages were experienced, one of the most noteworthy being the reduction in friction with a consequent increase in carrying capacity for any particular diameter. This has been found in actual practice to be of the order of 10 to 15 per cent. The reduction in friction arises from the mirror-like surface which is obtained as a result of the spinning operation.

The natural development, following the success of this type of lining, was in the direction of increased simplicity and reduced cost, and this step has now been taken in the production of the lining generally known as spun lining (as distinct from bitumen lining). The underlying principles are very similar, but the pipe, when finished, has a lining with a minimum thickness of 1/16 in. Except in cases where the water being carried is extremely acid or in the case of pipes used to convey acid effluents from chemical works, experience has shown that lining of this thickness is more than adequate to meet all ordinary conditions of service. It has, in effect, all the advantages of the original thick bitumen lining with the added advantage of reduced cost, increased effective bore for any particular size of pipe and greater shock resistance due to thinner coating.

The selection of suitable bitumens has been the matter of a very considerable study. It is necessary that the material should not only meet the

corrosive conditions met with in service but that it should be sufficiently resistant to temperature influences not only in service but prior to laying. It is further necessary that it should be sufficiently hard and elastic to resist the somewhat severe mechanical handling to which pipes are subjected before being finally laid.

The following figures give some idea of the nature of the material used and the properties which it exhibits after the incoropration of the mineral filler.

Melting Point (ball and ring method).....	220 to 240° F.
Specific Gravity.....	1.2 to 1.4
Penetration at 77° F., 100 grams, 5 secs.....	13 to 15
Penetration at 115° F., 50 grams, 5 secs.....	20 to 25

Experience over the last ten years has shown that, so far as the internal protection of the pipe is concerned, the centrifugal application of suitable bituminous coating has solved the problem of the protection of steel pipe for the conveyance of water even when it has extremely unfavorable characteristics from the corrosion point of view.

DEVELOPMENT AND USE OF SPUN BITUMINOUS COATINGS FOR WATER PIPE IN THE UNITED STATES.

BY GEORGE E. BOYD.*

[*Read September 22, 1937.*]

The bugaboo of soil corrosion no longer exists.— If that statement was made today to the effect that pipe lines could be buried in the most corrosive soils anywhere in the United States with positive and definite assurance of freedom from soil corrosion, it would sound pretty revolutionary to the average layman. And yet, this is not only theoretically possible, but is actually being done. Thus far have corrosion preventive methods progressed within the last few years. Progress and development of coatings, like progress in any other field, has been brought about because there was a real need for improvement, for the attainment of which somebody was willing to pay (call it the old profit motive, if you will) and because losses due to corrosion were rapidly mounting. It was only a few short years ago at a meeting of the American Society of Mechanical Engineers that the chief engineer of a large pipe line company estimated that the loss to pipe owners from soil corrosion in the United States alone amounted to at least one hundred million dollars each year.†

Historical. As far back as 1921, E. R. Shepard‡ of the Bureau of Standards reported approximately 138 000 miles of gas lines and 110 000 miles of oil lines in use in the United States. These lines, exclusive of water works lines, constitute an underground railroad system approximating the railroad mileage of our country and one of the largest and least known transportation systems in the world. It is estimated that there was invested in oil pipe lines alone over eight hundred million dollars as far back as 1928. It is self-evident that soil corrosion and the development of proper preventives was a problem needing immediate attention.

In referring to oil and gas lines, it is the purpose to call the attention of the water works associations to the amount of pioneer work that has been done by these utilities, because the nature of their business made it imperative that something must be done immediately; whereas the allied water works industry, due to its nature, could proceed in a much more leisurely fashion. It is due to the gas line owners and oil line owners and through their respective organizations, the American Gas Association and the American Petroleum Institute, that improvements in pipe-line coatings were started and later spread to the water works field. The American

*District Manager, Wailes Dove-Hermiston Corporation, New York, N. Y.

†C. R. Weidner, Chief Engineer, Prairie Pipe Line Co.

‡Gas Age Record, September 5, 1921, Bureau of Standards.

Gas Association and the American Petroleum Institute sought means to improve methods of protecting pipe from corrosion just as the New England Water Works Association has, through its committees, sought to improve the means of minimizing tuberculation. Therefore these associations, in conjunction with the Bureau of Standards, outlined and conducted a series of tests in which coating manufacturers were invited to participate by furnishing samples of their materials.

Data developed in these tests indicated to a great extent the relative value and weakness of various types of coatings and spurred manufacturers on to improve their products to overcome the weakness described. It stimulated research work resulting in improved materials, new methods, new mechanical equipment, all to the lasting benefit to the industry concerned. If the bait in the form of expected rewards for improved products had not been held out to coating manufacturers, because of the terrific toll taken by soil corrosion, it is doubtful if any manufacturer would have particularly fostered expensive research, no matter how badly needed. When we are inclined to grumble at times because of the sloth of the manufacturers not changing their products to suit our particular needs, might it not be worth while to consider whether or not we could or would be willing to pay a slightly higher price to help a manufacturer defray part of the cost of the research work involved in such changes or whether the law of the lowest price must always prevail.

At any rate, through these tests much valuable information was obtained, and some manufacturers, taking advantage of it, were enabled to improve their products to satisfy the newly-found conditions and to conform their product to the requirements demanded for protection for each particular type of soil.

Spun linings and coatings are one of these developments. In order to show the development of spun linings and coatings for water works it is necessary briefly to review the history of what was taking place in these tests. A brief summary of the present status of soil corrosion data, as found by the Bureau of Standards, American Gas Association and the American Petroleum Institute test, indicates: (1) that cold coatings such as paints, emulsions and inhibitors are worthless for prevention of underground corrosion and that greases do not prevent corrosion, but do somewhat reduce pitting, but are not good if cathodic protection is to be used; (2) that hot coal-tar enamels, by which are meant heavy coal-tar products containing a certain proportion of inert mineral filler to give structural strength, are generally the best type of protection yet found and are generally better than hot asphalts because they do not absorb moisture as asphalts do.

Soil Tests. In some locations in this country it was found that certain soils, notably alternately wet and dry clays, cause a stress to be put upon the coating, resulting in a distortioning and roughening of the coating surface. This fact was only discovered a few years ago. It then became necessary for the coating manufacturers to find a means of overcoming this

soil stress. A certain measure of additional resistance to soil stress was brought about by raising the melting point of the bituminous coating and using a harder type of material. This, of course, would have its disadvantages in cold climates where enamel with a high melting point might cause cracking in cold weather. Another method was to apply a wrapping of fabric or paper or even a cement or metal shield over the coating. At first these wrappings were applied by hand, but the coating manufacturers soon developed machinery and equipment for doing this mechanically.

The machinery and methods used in spinning on linings and coatings are generally well known so that it does not seem advisable to take time at this point to go into the mechanical side of the problem.

Pipe Lining. At about this time, water works engineers were becoming dissatisfied with the inferior tar and asphalt dips used on pipe lines. These dips were generally too thin mechanically to give adequate protection against tuberculation in aggressive eastern waters. The cast-iron foundries were looking for something thicker and more permanent than these dips, both for their own advantage and to satisfy the engineers. Hot coal-tar enamels had had a long record of satisfactory performance, but heretofore had been applied by hand on large diameter pipe only. Cement linings, too, had their drawbacks. All these factors brought about coöperative experimental work that resulted in the spun bituminous lining now being so universally used with aggressive waters. There were still many difficulties to overcome—poor bond, blistering, cracking in winter, sagging in summer. Causes of these troubles had to be ferreted out and remedies found. It was noticed that blistering did not occur on steel pipe or on the barrel of De Lavaud pipe, but only on the bell which was sand cast, and it was gradually learned that blistering or its elimination depended a great deal on the type of metal; the porosity of the pipe; the temperature at which the pipe was dipped into the priming solution; the freedom of the pipe surface from grease and oil and many other factors, some of which also affected the bond.

Numerous experiments were tried, such as sand blasting the metal surface; raising the heats on the pit-cast pipe and aging. In general, aging of the pipe seems to bring about a cessation of the tendency to blister. Dipping the pipe in the priming bath while the pipe is at the proper temperature has a very important bearing on the bonding qualities. If the pipe metal is too hot the primer when applied becomes charred resulting in poor bond. If the pipe metal is too cold when dipped, the primer is thick and slippery, and when the pipe is exposed to the hot sun over long periods of time, the volatile solvents expand and push up blisters in the lining. All of these troubles can be eliminated by proper supervision on the part of the foundries. This is evidenced by the fact that many miles of perfectly lined pipe have been installed. The author ventures to say that of all the pipe lined with bituminous enamel in New England by the Warren Pipe & Foundry Pipe Co., there have been very few causes for complaint. This

is due to the supervision and care taken. It is not a difficult trick to spin a bituminous lining in a pipe, but the important consideration is the condition of the pipe: its temperature and cleanliness when dipped. The improvement in temperature ranges of the bituminous enamels was another forward step, because it no longer became necessary to condition the enamel for the particular season of the year in which it was to be laid. For the first time in history it had become possible to secure a coal tar enamel (with the better protection it provides) which has the physical qualities of the asphalts in regard to withstanding a much wider range of temperatures without sagging at the upper limit or cracking at the lower limit, but without the limitations of asphalts as a permanent protective material.

By this time the Bureau of Standards tests had progressed to the stage where it was recognized that certain coatings were practically proof against the chemical action of any soil anywhere in the United States, provided they could be perfectly applied.

Mechanical Application of Coatings. On most of these buried tests, only crude methods of application were then available, and there was always the possibility of inferior application, missed spots and holidays. Coatings having been developed to the state where they could take care of the chemical action of the soil have now, by use of mechanical spun applications, been freed from the probability of missed spots and holidays. On large diameter pipe, by rotating the pipe and simultaneously pouring and spreading the hot enamel, a much smoother and more uniform surface was obtained. On smaller diameter pipe, end-feed machines force the pipe through a bath of hot enamel so that it is impossible for a spot to be missed. Wrappings, if required, are also applied mechanically, and a second pouring of hot enamel assures adequate thickness of the bitumen next to the metal and completely seals down the entire surface of the wrapping. The possibility of even the minutest pinhole can now be entirely eliminated by using what is called an electric holiday detector. This apparatus generally consists of a Neon-sign transformer delivering about 15 thousand volts at about 50 milliamperes to a wire brush or screen which is passed over the coating surface. Inasmuch as good coal tar enamels have excellent dielectric properties, so long as the thickness is up to standard, the 15 000 volts will not break down the coating, but any thin spots or pinholes will immediately be shown up by sparking and snapping and can properly be repaired. The next step in improvement of pipe coatings was to find the method of eliminating soil stress. This soil stress is practially unknown in New England, and there are not many localities where it is a serious matter. However, often times coating resting in cinder fill or sharp gravel or sand containing seashells will become distorted or receive an imprint, thus making a thin spot, and in these types of soil it is advisable to provide some sort of a mechanical shield. The usual method is to use a felt or asbestos, tar-saturated wrapper, and in many, except the most severe locations, this

wrapper, over a good coal tar enamel coating which had been mechanically and electrically tested, should be sufficient protection.

Cathodic Protection. However, the engineer still has a further protection; we might say an ace up his sleeve. This is cathodic protection. Since all soil corrosion is now considered to be electro-chemical in action, and since corrosion only takes place where current leaves a pipe, if we build up an electrical pressure on the outside of the pipe, acting in the same manner as water pressure does, whereby the current seeks to force its way through any possible breaks in the coating to the metal and if this electrical pressure is about three-tenths of a volt more than any current coming off the line, it is impossible for the pipe to corrode. There is plenty of corroborative evidence to the effectiveness of cathodic protection, so that the statement made at the beginning of this paper to the effect that the bugaboo of corrosion in metal pipe need no longer scare the well informed engineer, can readily be substantiated.* This does sound as though there was a catch in it somewhere, and there is a catch in it. The catch is this—that the cost of using cathodic protection on pipe lines is relatively inexpensive provided the pipe line has a good thick dielectric coal tar enamel coating. This cost mounts considerably as the dielectric quality of the coating becomes poorer. But with a good dielectric coating, the quantity of current required to penetrate into small pinholes or missed spots is of negligible cost.

In this connection it should be remembered that some coatings furnish a protection for four or five years and then begin to disintegrate and that in contemplating protection it is important to secure a coating which has a long-time proven period of performance, because the quantity of current needed would, after ten or twelve years, rapidly increase should the coating deteriorate.

The introduction of cathodic protection is a relatively simple matter on cross-country supply lines. But lest the water works engineers be mislead, to apply this cathodic protection on a city distribution system would require the services of an expert. In New Orleans the gas mains of the New Orleans Public Service have been adequately protected by cathodic protection and no corrosion has taken place since 1928.†

Economics of Protection. To attempt to determine where coatings on buried pipe lines are necessary, various methods of soil analysis have been used, such as chemical analysis, measurement of hydrogen ion concentration and determination of resistivity. The difficulty of attempting such a task on any but the longest lines is that it takes an expert to determine this and even the expert's findings may be confusing, because the corrosivity of the soils may change from day to day due to different percentages of

*Cathodic Protection of pipe lines from soil Corrosion by Scott Ewing, Bureau of Standards, Gas Age Record, March 2, 1935.

†Theory and Use of Cathodic Protection, Robert J. Kuhn, American Gas Association, April 12, 1937.

alkalinity, acidity, soluble salts, increase of moisture, alterations in drainage, under-filling, stray currents, etc. Furthermore, often times soil varies from non-corrosive to corrosive within a single length of pipe. The Bureau of Standards findings tend to indicate that it is the thickness of the metal that determines the rate of pitting, rather than the kind of metal. From that it might appear that if the metal were made thick enough, leaks would be eliminated. Undoubtedly this is theoretically true; but unfortunately a pipe never fails due to uniform corrosion; it fails by pitting. If a pipe failed due to uniform corrosion, it would be a simple matter to add a few thousandths of an inch additional thickness for each year of desired life and thus obtain a pipe which would last indefinitely. But since it is pitting that causes the failure and pitting is concentrated on probably less than 5 per cent. of the entire pipe surface, where is the economy of adding additional thickness of metal, beyond that needed for stresses, to 100 per cent. of the pipe area to protect the 5 per cent. where pitting may occur. This is very much like a man building a wooden house, and in order to secure protection against fire, building the walls of wood 3 in. thick instead of the usual ⅞ in. Extra metal is the most expensive and poorest protection against corrosion. It might seem more desirable to use something more suited to the purpose, that is less expensive. In pumping of water and sewage the economics of a smooth, spun lining are shown in a brief history of the development of spun coating.

Pipe Line of Memphis Natural Gas Co. Figures 1 to 3 show the methods of soil survey adopted by the Memphis Natural Gas Co. on their 210-mile 18-in. steel main from Monroe, La. to Memphis, Tenn. This line is located entirely in the alluvial valley of the Mississippi River. The soil has a high clay content in both surface and subsoil, is generally poorly drained and in the hot dry season cracks badly. There are numerous stream and bayou crossings, and during the winter season it is not unusual to have about 20 per cent. of the line under water.

The original specifications called for a protective coating for the entire length of the line and left the selection of the coating to the engineer in charge. Hot enamel was used from the Monroe field up to and a few miles beyond the Mississippi River crossing. From this point on, through the State of Mississippi, both hot enamel and cold emulsion were used. As the line was extended toward Memphis the sections which were coated with hot enamel became shorter and farther apart and the last forty or fifty miles were coated with cold emulsion.

In 1931, the company's engineer reported that the line was fully protected with the exception of approximately ten miles in Mississippi where the cold emulsion was found to be crumbling and scaling off. In 1934, a thorough survey of the line with particular attention to electrolytic action was started. This investigation included a Shephard rod survey to obtain the necessary data on soil resistance and also the potentials existing between pipe and soil. Bell holes were dug at 600-ft. intervals, and the

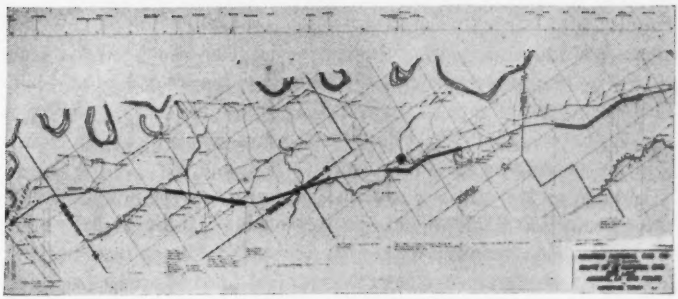


FIG. 1.—PIPE LINE OF MEMPHIS NATURAL GAS COMPANY ALONG THE MISSISSIPPI RIVER.

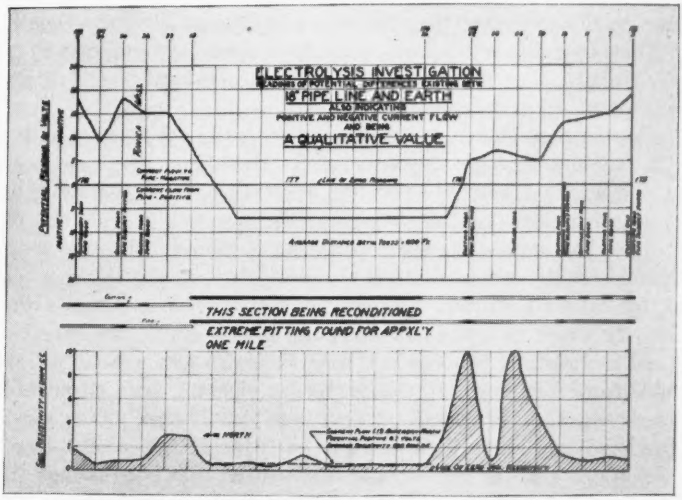


FIG. 2.—ELECTROLYSIS INVESTIGATION OF MEMPHIS NATURAL GAS COMPANY'S PIPE LINE.
Showing change from negative to positive current flow.

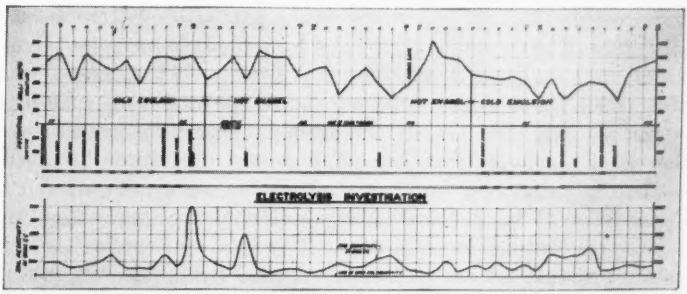


FIG. 3.—ELECTROLYSIS INVESTIGATION OF MEMPHIS NATURAL GAS COMPANY'S PIPE LINE.
Showing difference between protection by asphalt emulsion and by coal-tar enamel.

pipe was carefully examined. Where corrosion was found to be in progress, additional bell holes were dug to determine the length of line affected. As a result of this investigation, the company reconditioned 22½ miles of the line in Mississippi, all of which had been originally coated with cold emulsion. The reconditioning was done with hot enamel. At the same time the company, on the advice of its engineer, adopted the policy of applying cathodic protection to those sections of line where coating failure had commenced but where corrosion had not progressed to the point where the pipe was seriously affected. As a result, there is a total of approximately forty miles of line on which cathodic protection has been applied. This is in addition to the 22½ miles of reconditioned line which, being electrically continuous and joining a section of protected line, is getting cathodic protection due to the excellent insulating qualities of the enamel coating.

The writer wishes to acknowledge the courtesy and coöperation of Mr. H. C. Wallace, Vice President of the Memphis Natural Gas Company for this information on their pipe line studies.

Figure 1 represents a general map of the section of some 20 to 25 miles of this pipe line showing the bends in the Mississippi River and parallels. Figure 2 shows a section where the current, as measured by potentiometers, earth current meters, changes from negative to positive. Where the upper line crosses the zero rating and continues below the zero line, this indicates the current leaving the pipe. It is at this location that we look for severe corrosion. Incidently, the lower curve shows the soil resistivity which at this particular place is also low. Low resistivity of the soil as measured by Shephard rods, indicates also a place to look for trouble from corrosion. In this particular diagram, both elements likely to cause corrosion are present, and it is seen that extreme pitting was found at this locatlon. Figure 3 shows very clearly the difference between asphalt emulsion and coal-tar enamel, and it is noticed that even though the soil resistivity is low, where the hot enamel has been used, there has been no evidence of corrosion, whereas the pitting on the section of the pipe coated with asphalt emulsion is quite severe.

Summary. In this paper the writer has attempted to set forth: (1) that there is an enormous annual loss due to underground pipe corrosion; (2) that there has been developed but one relatively inexpensive type of coating which has shown qualities superior to any other — namely coal tar enamels; (3) that these enamels are adequate protection against chemical action of the soil; (4) that heretofore perfect application has not been possible. But that now by the use of mechanical equipment and spun coatings followed by electrical testing devices, perfect application can be obtained; (5) that soil stress is not very general, but confined to certain localities and that the use of properly applied wrappings will, to a great extent, minimize this, if not entirely prevent it; (6) that with the addition of cathodic protection to a properly coated pipe line, there is no excuse for a metal pipe line ever to corrode and that such protection is relatively cheap

when applied in conjunction with a good coal tar enamel; (7) that while it may be theoretically possible to determine the corrosivity of a particular soil in which a pipe is to be buried, from a practical standpoint the average engineer or superintendent has not the means, the equipment nor the knowledge to undertake such surveys and furthermore they are hardly warranted except in the case of the longest lines; in the case of short lines, such as the ordinary water department would have — not over a few miles — and salvage value and other things considered, it would be better to coat the entire line; (8) that since it is practically impossible to predict accurately where pitting will take place, it would seem to be good engineering economics to figure the thickness of metal for stresses only and add the best possible coating which would ordinarily be cheaper and better suited to prevent corrosion than extra metal; (9) that with the advent of new equipment for applying spun lining and coatings and mechanically protecting pipe lines, perhaps the ultimate answer to the problem of pipe line corrosion will be for the progressive coating manufacturer to assume complete liability for the protection of the pipe line by making the necessary soil surveys, recommending the proper type of protection for that soil, and deciding whether cathodic protection should be adopted or not, applying the coating himself and then furnishing a maintenance agreement guaranteeing the freedom of the pipe line from leaks due to corrosion.

QUALIFICATIONS OF OPERATORS OF WATER TREATMENT PLANTS

BY WARREN J. SCOTT.*

[*Read September 23, 1937.*]

In many parts of the country, where public drinking water supplies must be taken from turbid and polluted streams, filtration plants have long been necessary adjuncts of public water supply systems. The State of Connecticut, in contrast, has no public water supplies derived from polluted streams, most of its cities and towns securing their drinking water supplies from streams and reservoirs in relatively clean upland areas. A few ground water supplies are also in use on public systems. The same situation with regard to quality of public water supply sources applies in most of the other New England states.

A recent development in the water supply field has been a rapid growth of public interest in elimination of high color and objectionable taste and odor from public water supplies. This development has led to a decided increase in the number of water filtration plants. Most of these plants are of the rapid sand gravity type. The fact that these plants need competent supervision has induced the Connecticut State Department of Health to seek the passage of legislation to assure appointment of qualified personnel to direct plant operation. The 1937 General Assembly of Connecticut amended one of the existing water supply laws to this effect (Chapter 140 of the 1937 Public Acts).

Interest in the subject of licensing or approval of water works operators has been noticeable in recent gatherings of water officials. In order to obtain a cross-section of policies being followed in the various states, information was requested from the sanitary engineers of the various states. Replies were received from all 48 states,— an extremely commendable response,— and these indicate the following:

Number of states without any specific laws or regulations controlling *appointment* of water treatment plant operators	41
Number of states without any specific laws or regulations controlling *qualifications* of water treatment plant operators	40
Number of states without specific laws or regulations but having authority to pass on appointments under general laws	2

The states reporting the existence of specific laws or regulations dealing with treatment plant operators are California (on appointments), Connecticut, Kentucky, Michigan, New Jersey, New York, Ohio, Washington, and West Virginia. This is not an impressively long list. However, several other states reported that the matter was under discussion. In four

*Director, Bureau of Sanitary Engineering, Connecticut State Department of Health, Hartford, Conn.

states — Colorado, North Carolina, Texas and Wisconsin — legislative bills have been recently proposed but have so far failed of enactment. In Texas, it is reported that a voluntary scheme of certification has been worked out whereby certificates or licenses are granted to water plant operators, thus tending to raise the standing of qualified men.

In order to gain an insight into various laws and regulations, the provisions of present laws and regulations in the states previously mentioned are discussed briefly. The Connecticut law already referred to provides that the qualifications of the operators of water treatment plants of any municipalities, public institutions or water companies shall be subject to approval by the State Department of Health. An almost identically worded law with regard to sewage plant operators was enacted in Connecticut four years ago. California's law provides that the State Board of Health may order the appointing of a competent person, to be approved by the State Board of Health and paid by the water supply management, who shall take charge of and operate a plant or system so as to secure the results demanded by the State Board of Health. Through the California section of the American Water Works Association, a voluntary system of certification has been developed. This provides for the issuance of first class, second class and third class certificates after examination, similar to legally required certificates in other states, as discussed later.

The Kentucky state law provides that "the State Board of Health is empowered to provide standards of qualifications and issue certificates for the operatives in water and sewage plants." Michigan has regulations which set up an examining board of three members appointed by the State Commissioner of Health to pass on applications for licenses to operate filter plants. First and second class licenses are issued. Provision is further made that the State Department of Health may require that a certified analyst supervise disinfection plant operations. The three members of the Michigan examining board must include a sanitary engineer from the State Department of Health and at least one superintendent of a water treatment plant. Operators of plants employed at the time of passage of the regulations are not affected. Ohio has recently adopted regulations requiring that water treatment works shall be under the supervision of a trained individual who is certified by the State Director of Health provided that this shall not affect present employees continuing in office. Further provision is made in the regulations for establishment of a classification of such supervisory individuals and operating personnel.

The New Jersey law authorizes the State Department of Health to conduct examinations to determine qualifications of operators of water treatment plants and provides that such plants must be under supervision of licensed operators except in the case of continuation of personnel employed at the time the act was passed. First, second, third and fourth class licenses are issued to qualified operators. Applicants for New Jersey licenses must not only qualify according to the stated requirements but must obtain a mark of 70 per cent. arranged from written and oral examinations. The

State Department of Health may revoke licenses for cause. The New Jersey license law is so well known in the East that it is of some interest to compare the classifications and requirements with those in California and Michigan. The accompanying table shows the comparison. It is to be noted that there is considerable similarity in the ranges of requirements in Michigan and New Jersey.

In some respects the New York law is like the Connecticut law, but the New York law peculiarly limits the power to regulate the qualifications of water plant operators to those paid out of public funds. It, therefore, does not appear to apply to private water companies.

The Maryland State Board of Health can appoint an operator to replace an incompetent operator. In Massachusetts, most municipal employees are under state civil service although no definite qualifications have been set up for water treatment plant operators. The Washington State Board of Health has adopted a regulation to the effect that "a competent person, familiar with the principles and operation of a water supply and water purification plant, where treatment is required, shall be in charge of each plant. Said person shall be approved by the State Director of Health." More specific requirements are under consideration.

West Virginia has regulations requiring operators of water treatment plants to be licensed by the State Department of Health. The program has had the backing of the State Water Purification Conference and privately owned plants. Written examinations are given to applicants for licenses and are passed upon by a board of three: one member from the State Department of Health, one member from the State University, and one representative of the State Conference on Water Purification. First, second and third class licenses are issued.

In Wisconsin a proposed law was introduced to provide that in the future all water and sewage treatment plant operators must have a certificate issued on the basis of examinations given by a committee of sanitary examiners composed of the State Sanitary Engineer, a member of the Wisconsin section of the American Water Works Association, and a member of the Conference of Wisconsin Sewerage Works Operators. The latter two members were to be appointed by the State Board of Health from lists submitted by the two organizations. This law, however, failed of enactment in the 1937 legislature.

The proposed law in Wisconsin tying up the certification of water treatment plant operators with the water works association membership sets up a procedure already followed in Michigan and West Virginia. In Oregon, it is planned to set up a school for water works operators with optional examinations and issuance of certificates to operators qualifying by examination. The Water Works Association of South Carolina has worked out with the State Board of Health a voluntary system of certification, and it is expected that with the betterment of training among the operators, eventually a legal requirement for qualifications of operators

REQUIREMENTS FOR WATER TREATMENT PLANT OPERATORS.

State.	FIRST CLASS QUALIFICATIONS.		Type of Plant.	SECOND CLASS QUALIFICATIONS.		Type of Plant.	†THIRD CLASS QUALIFICATIONS.		Type of Plant.
	Training.	Experience. Years.		Training.	Experience. Years.		Training.	Experience. Years.	
C*alifornia.....	College degree.	1–3	Any treatment process as chief operator.	High school plus some training or examination.	2	Operators of any treatment process.	Examination.	2	Subordinate operators and chlorinator operators.
	Two years college.	5							
	High school or less.	5–10							
Michigan.....	College graduate and training.	2	Filtration and water softening.	High school plus adequate training or examination.	....	Operators of filter plants but not filter and softening plants.	Adequate.	Adequate.	Disinfection plant supervision.
	Private study.	6							
New Jersey.....	....	6	Filtration plants, over 2-m.g.d. capacity. Other plants, 20-m.g.d. or above.	....	4	Filtration plants, less than 2 m.g d.	....	2	Filter plants without coagulation less than 2 m.g.d. Disinfection plants 2 to 10 m.g.d.‡
	Two years.	4		One year.	3	Disinfection plants, 10 to 20 m.g.d.	One year.	1	
	Three years.	3		Two years.	2				
	Technical college degree.	1		Technical college degree.	1				

*Voluntary only. †Termed "analyst" in Michigan. ‡New Jersey also has fourth class for small disinfection plants.

will be made. The Georgia Water Works Association also has a voluntary plan of certification of operators.

As noted from the foregoing, there are at present two somewhat different policies followed out in those states regulating qualifications of operators of water treatment plants. One provides for a definite licensing plan with issuance of licenses of various grades. Appointments to any plant must presumably be made from the group of licensed operators available. The other provides for approval of qualifications only and allows a community to select a candidate and present his qualifications for approval. The distinction is somewhat fine perhaps but the first of the two methods involves somewhat closer state control. In Connecticut we feel that the second method is functioning effectively and adequately fulfills the needs.

One plan which appears to be working out satisfactorily in Connecticut is to allow a small community to employ a relatively inexperienced operator, with some chemical and perhaps bacteriological training, to take over the operation of a water filtration plant after a short intensive period of instruction by a competent chemist and bacteriologist with a further provision that for the first year of operation at least, the consultant will keep close supervision over plant operation, such supervision including two or more field visits to the plant each month with examination of check samples in the consultant's laboratory. In this way, we expect to develop satisfactory operators where better trained operators cannot readily be installed. The consultants have so far been drawn from private practice, although it is possible that a well qualified operator in a large city might serve as consultant or supervisor to a man in a smaller community if the policy were approved by both communities.

The supply of qualified operators presents a problem. It is somewhat simplified by the fact that as state laws are enacted to provide for appointment of qualified operators of water treatment plants, they usually carry the so-called "grandfather" clause exempting present operators. Consequently the demand grows gradually as new plants are built or as old operators are displaced by retirement, death or other reason. It is to be noted in the New Jersey requirements, experience receives a substantial favorable allowance. Only in the case of a technical college graduate, does the amount of acceptable experience drop to one year. The experience requirement is undoubtedly a wise precaution. However, where water filtration plants are not so plentiful and where frequently only one man at a plant may be qualified by training to assume charge of a plant without a supply of qualified assistants who might fill supervisory positions in other plants, the requirement of experience is a stumbling block. One way to get around it is to allow for inexperienced operators starting out under good supervision as already commented upon.

In a large filter plant, there is usually considerable mechanical equipment in the way of pumps, motors, chemical feeding devices, etc., and it is desirable to have on the operating staff a repair man of experience. Frequently the superintendent or operator is a chemist and bacteriologist who

has not had the mechanical training or experience to make important mechanical repairs. It is necessary that the state supervisory body make this point clear to municipal authorities.

Another lack often found among young men who have the necessary training to operate a water treatment plant is that of experience in handling and getting along with other men. Many plants operate on three shifts, and in larger plants more than one man may be employed on each shift. Sometimes it is not possible to get away from the appointment of inexperienced and untrained assistants who may be older men, perhaps with a political background. Tact and experience are required to get satisfactory service out of such assistants. A strong stand may prove necessary to establish authority. Of course, the situation may be that the superintendent of the water system, usually a man of experience with authority, may have the time to "boss" the staff at the filter plant and thus assist the plant operator, but very often the superintendent does not have the time and the plant operator must take it upon himself to develop a smooth running plant staff subject to discipline. The important attributes of tact and willingness to work can hardly be disclosed by examinations but may be brought out by following up an experience record.

Apparently in most states, the procedure is to qualify the plant operator or superintendent and make him assume responsibility to see that the work of the assistants is such as to produce satisfactory results. There is every reason to work not only toward the placing of qualified superintendents in water treatment plants but also toward better trained assistants, especially in larger plants. The availability of a substitute to take charge of a water treatment plant in case of sickness or of accident to the plant superintendent is an important consideration, and some solution should be worked out to anticipate such a need at each plant. Sometimes, there is a good assistant operator to carry on. On some small systems, the water works superintendent may be able to carry on temporarily. I have known of one case where sickness of two filter plant operators made it necessary for a city to turn to a filter equipment concern for temporary help.

The relationship between qualified operators and the state health agency is usually cordial. I do remember one meeting with a licensed third class sewage plant operator in one state who had been turned down upon application for a second class license, telling me that he wouldn't let any of the unmentionables from the state health department on the grounds of his plant. This, however, is an exception. The fact that there is such a cordial relationship sometimes leads the superintendent or operator to feel that he should be licensed by the state and be principally responsible to the state agency rather than the municipality. He also may feel that tenure of office should be brought about in the same way. This would in his opinion take the job out of politics and not subject him to possible whims of changing municipal administrations. Of course, the way is open to provide tenure of office by setting up civil service in any community which is interested.

It must be borne in mind that the water plant is owned and operated by the municipality and paid for out of municipal funds. Even though politics may at times work rank injustice upon capable operators, it is doubtful if the state should go further than to insist upon employment of a qualified man. Certainly in New England, local communities, while decidedly coöperative with state agencies, are reluctant to relinquish their local prerogative of "hiring" and "firing." If replacements must be made from the ranks of qualified men, this tends to discourage changes. Changes are usually made because it is desired to make way for some political henchman. In the long run, the operator must sell himself to the community and his superiors. This he can do by faithful attendance to his duties and constant effort to better his knowledge by attending schools or conferences on water plant operation and by keeping abreast of developments through visits to other plants when practicable and through reading water works journals and magazines where the other fellow's studies and experiences are discussed.

Concluding this paper with its summary of progress in various states in setting up qualifications for water plant operators, it is probably true that in most states without any set requirements, the state health agency may exercise some control either by power to act in emergencies brought about by faulty operation of a water treatment plant or by some provision in approvals granted for construction of new plants to the effect that plants must be properly operated. It does not seem, however, that such general provisions are adequate.

There are definite advantages to be gained from specific laws or regulations establishing qualifications for water plant operators. They keep out the unqualified man from positions involving a large measure of public health responsibility; they raise the calibre of operators of water treatment plants with opportunities for more adequate salaries; they elevate the position of the operator in the public mind; and they tend to aid in creating public sentiment for tenure of office for qualified men.

The art of water treatment and the health of water consumers will be greatly advanced by efforts of members of such water works associations as this to promote the enactment of laws or regulations requiring that qualified personnel be in charge of operation of water treatment plants. Where laws and regulations have already been enacted they should receive the hearty support of water officials. The sooner the public gets the idea that the business of operating a water works is a profession rather than a political football, the better will the public be served.

THE NEEDHAM GRAVEL-PACKED WELL.

Deductions from Investigation and Operation.

BY BAYARD F. SNOW.*

[*Read September 23, 1937.*]

Since last February the town of Needham, Mass., has been furnished a large part of its water supply from a gravel-packed well located in the south-westerly corner of the town about 600 ft. from the Charles River. For two reasons the quantity supplied from this source has been less than the total consumption: one being that the mains between the well and the storage tanks, or the centers of distribution, are not yet adequate in capacity to carry, except at excessive friction loss and excessive pressure, a flow equal to the normal use of the town; the other being that it is thought desirable in the interests of long-time economy to limit the draft from the well to an amount well within the proved safe yield. The feeling of satisfaction which the officials and inhabitants of the town of Needham have in this new source of water supply and the interest that has been displayed by water works men from other communities in New England appear to be thoroughly justified, and the performance of the well and appurtenances since they were placed in regular operation fully meets the expectations of those who worked upon the investigation and design of the works and the hopes that led up to such investigation and design.

General Interest in Demonstration. During, and subsequent to, the testing of the well there has been much interest displayed, not only by engineers and water works men but by the general public. Some of the publicity that first caused this interest and then resulted from the continuation of that interest gave rise to rumors that had the well doing everything from tapping a large underground river to its breaking into and releasing a geyser, the equal of anything seen in Yellowstone National Park. A demonstration of the well, after the official pumping test, was more spectacular than scientific, but if it called attention to the valuable underground water supply,—that frequently remains undiscovered because of the failure, generally on the part of public officials who control the purse strings, but possibly chargeable in part to engineers and water works men, to devote sufficient intelligent and persistent search for the best available location and means of collecting underground water before deciding upon a more costly program looking toward a surface water supply,— the publicity will have been well worth while. Available and satisfactory sources of water supply are not so plentiful that we can afford to disregard any of them. The volume of water that is absorbed by the soil and flows underground to the ocean is tremendous. The danger of pollution to such

*President, X. Henry Goodnough Inc., Engineers, Boston, Mass.

a supply is generally less than with surface waters. Evaporation and leakage losses can be ignored. Condemnation of land is negligible. Cost of development is usually much less than that of impounding reservoirs of comparable yield. There remain, therefore, the problems of locating such a source and designing collecting works best to utilize this ground water.

Local Conditions Favorable. Lest there be any misconception, it should be stated at once that the Needham well merely utilizes the natural underflow of the Charles River Valley to the fullest extent thought desirable by one well and that it takes advantage of the natural deposit of a large and deep sand and gravel stratum as a storage and collecting system. The town is fortunate that Mother Nature provided this large aquifer and reservoir and that it was possible to discover it with the somewhat limited funds that were provided for the survey and investigation. There is no reason to believe that the conditions in Needham are unique or that similar ground water developments are impossible elsewhere, although it is recognized that the local conditions were exceptionally favorable.

The Charles River. The location of the town with respect to the Charles River and to its more rapidly growing neighbors has had an influence upon the development of its water supply resources. Reference to the watershed (Fig. 1) will show the meandering course of that river. Rising in Hopkinton about twelve miles southwesterly from the point where it first reaches Needham it flows many miles in a southerly, easterly and northerly direction, finally reaching Needham from the north after looping through the southerly corner of the town of Wellesley. Where it first touches Needham, it turns south-westerly for a short distance then flows easterly to form the southerly boundary of the town. After making a loop through Dedham it flows north-westerly between Needham and Newton and then swings around to the north and east to discharge into Boston Harbor after its waters have been held for a period to form the beautiful Charles River Basin. A large part of the watershed has been sparsely settled, and it is natural that the faster-growing towns of the metropolitan area should have looked to the Charles River Valley for ground water supplies. The taking of land within the limits of the town for the development and protection of water supplies for her neighbors has left Needham in the peculiar position of having more frontage on the Charles River than any other town along its course and yet being forced to consider a water supply from other sources.

Draft from Watershed. The valley of the Charles River has served for many years as a source of water supply for the municipalities and industries that were there located, most of such supplies being taken from wells or filter galleries. Tributary to the Charles River, as it enters or first comes in contact with the town of Needham, is a watershed of 180 sq. miles, including all or large parts of the towns of Milford, Bellingham, Franklin,

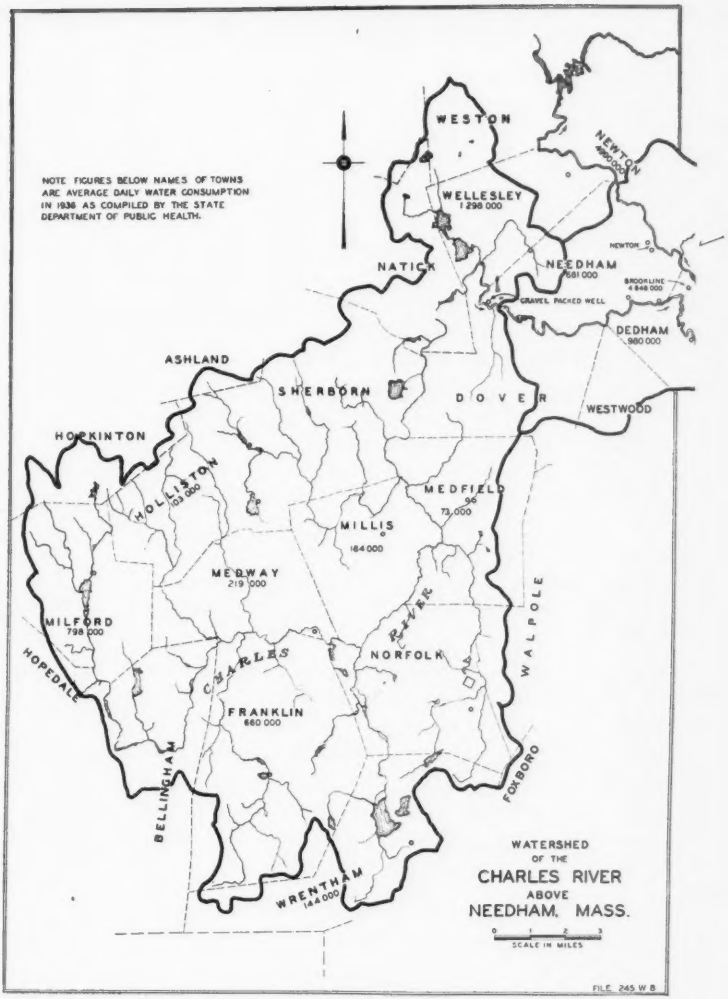


FIG. 1.

Wrentham, Norfolk, Medway, Sherborn, Millis, Holliston, Medfield, Dover, Natick, Wellesley; with smaller parts of the towns of Hopedale, Hopkinton, Ashland, Framingham, Weston, Walpole; and even a part of Needham itself. From this area are taken all or part of the water supplies of Milford, Holliston, Medway, Franklin, Wrentham, Millis, Medfield, the State Prison Colony at Norfolk, and various commercial and industrial establishments aggregating 2.5 m.g.d. for public water supplies alone. As the river loops around the town and forms its southerly and north-easterly boundaries, there is an added tributary area of 40 sq. miles including parts of the

towns of Dover, Dedham, Westwood, Brookline, Newton and of the city of Boston. From this added area are taken the public water supplies of Needham, Newton, Brookline, and Dedham aggregating 11.5 m.g.d., all of which, with the exception of the Needham supply, are collected within an area included in a diamond-shaped figure about three miles long by two miles wide, located in the main river valley. Although a total draft of 14 m.g.d. from a watershed of such magnitude is far from excessive, the taking of the greater part of that quantity within this comparatively small area is bound to tax the hydraulic capacity of the water-bearing strata, exhausting the underground storage in the neighborhood of the points of collection and drawing down the water level so as adversely to affect both quality and quantity, particularly in the summer season when yield is small and draft considerably higher than the figures just given.

Diversion by Mother Brook. Another factor which influences the total yield from the watershed, or at least the total of the surface and underground flow past the downstream corner of the town of Needham, is the diversion by Mother Brook into the Neponset River of a substantial part of the yield from the Charles. This canal, under legislative authority, is entitled to divert one-third of the flow of the Charles River to Dedham, the point of diversion being about half way between the south-easterly corner of town, where the river starts a loop through Dedham, and the point where it again touches Needham to form the easterly boundary of the town. The influence of this diversion upon the available ground water in the Charles River Valley below this point may be negligible; but even if the underground diversion is equal to that of the surface water, the difficulty in securing adequate well supplies below this point lies not in the insufficiency of drainage area but in the nature of the collecting medium. The net watershed at a point just below Mother Brook, after deducting one third of the total, is still 132 sq. miles, from which area the average draft for municipal supplies is about 100 000 g.p.d. per sq. mile.

Analogy to Surface Water Supplies. It has frequently seemed to the writer that the various factors that play important parts in determining the adequacy of a ground water supply can be understood better if a comparison is made with the corresponding factors in a surface water supply. In fact, our surface water supplies are, to a large extent, maintained by ground water flow, and it is necessary, in developing such supplies to anything more than a small fraction of their capacity, to prevent the escape of water by underground channels. It is also true, in many cases, that the available storage per foot of draft is greater at low-water levels in a reservoir than when the water level is higher, showing that much of such supply is stored in the porous earth. The yield of any water supply is dependent, as we all know, upon the watershed tributary to that source. This is true whether it be a ground water supply or a surface water supply and, in the absence of evidence to the contrary, we may assume surface

indications of the limit of the tributary watershed. It frequently happens that a superficial divide is underlain by porous material which would readily permit the passage of water to or from the collecting point, but this is true whether the collection be in an impounding reservoir or in an underground reservoir consisting of a deep and extensive body of coarse sand and gravel. In the surface reservoir, a porous stratum through the dam or divide causes loss of storage or diminution of effective watershed. With an underground supply, the effect conceivably can be a gain of effective watershed by drawing water toward the well.

In underground storage, as in surface storage by natural or artificial impounding reservoirs, the relation between the volume of the reservoir and the area of watershed is a factor in determining the safe yield. Such storage is necessary to permit the utilization of the periodic run-off from storms when and as the supply can properly be used. If no lowering of the ground water level in a dry season can be noted, or if pumping at a high rate appears to have little effect, there is either a satisfactorily large storage or an underground flow of such magnitude that the amount withdrawn is relatively insignificant. With surface water, we can readily see these two conditions: a small stream, dammed naturally or artificially to give storage of such volume and surface area that draft has little chance to lower the level by any appreciable amount before replenishment sets in, or a river of such magnitude as to show no effect of this draft. It is probable that most of our satisfactory underground supplies resemble the latter condition more than the former, but there is the added condition that, in general, slopes are flat, velocities low and a slight lowering of the water surface by pumping will draw from all directions, giving the effect of a reservoir.

With an open reservoir, the type of intake works is a factor in determining the total amount of work that will have to be done in making the water available for use under the desired pressure and must be taken into account in designing the pumps and determining the level at which they are to be placed. These same factors are of considerable importance in the collection and use of underground sources of water supply. Frequently, they are so considerable as to make too great a lift for pumps of the suction type placed at acceptable elevations.

We have, therefore, the same three factors that determine the proper design of a ground water supply as are applicable in the case of surface waters: (1) the tributary watershed must be sufficient; (2) the reservoir must be adequate to provide storage to compensate for the differences between replenishment and draft; and (3) the hydraulic capacity of the collecting works must be such that the loss of head may be kept at a minimum.

Adequacy of Watershed. The first of these conditions would be met at any point in the Charles River Valley within the town. Obviously the farther downstream the point of collection, the greater will be the tributary area, but since the suitable territory in the easterly part of the town was

already largely taken for water supply purposes and since the metropolitan trunk sewer precluded the development of any ground water supply throughout a large part of the southerly boundary of the town, there remained little opportunity to locate collecting works that would draw from the underground flow in the river valley itself. For any such draft as will be necessary for many years to come, the tributary watershed of the Charles River, as it enters the town, is much more than ample.

In an exhaustive article on the groundwater of western Long Island,* William F. Laase states: "In the easterly part of Nassau County, a safe yield could be secured in excess of 1 m.g.d. for continuous operation, and as high as 1.25 m.g.d. per sq. mile for intermittent operation, by a complete development of all subsurface sources. . . ." And lest the question of the source of the Long Island groundwater supply be raised, we may add that William W. Brush, in discussing Mr. Laase's paper, says: "The investigations that have been made during the past two years . . . have clearly shown that the sub-surface waters of Long Island have their origin in the rainfall on the island."

Storage and Hydraulics. Although the analogy has been drawn between surface water storage, with intake works and pumping equipment, and underground storage, with well or other collecting agency and its appurtenant equipment, the line between the functions of storage and hydraulic capacity appears to be clearly drawn in the case of a surface reservoir, and almost non-existent in the case of an underground supply. In a reservoir the slope or head loss between the influent stream and the point of intake where the water leaves the reservoir is so slight as to be negligible, whereas in the case of an underground supply the loss in flowing through the interstices in the sand or gravel to the collecting point is always of considerable magnitude and frequently the determining value in fixing the safe draft. Examination of the nature, depth and extent of the various strata in which the water is stored and through which it must flow to the well is possible by wash borings which can and do disclose much valuable information. Such data pertain more to the nature of the reservoir than to its volume or area and so are of interest in studying the hydraulic capacity rather than the gross storage. The porosity of fine sand or clay and the volume of water stored in those pores may be equal to those of coarse sand or gravel or greater than those of graded gravel, but its permeability is but a small fraction of that of the latter. If sufficient test borings could be made and samples of the different strata analyzed so as to give a comprehensive picture of the entire earth-filled basin for several thousand feet from the collecting point, it is possible that by involved mathematical computations, the drawdown could be determined for various rates of draft. The nature of our glacial deposits is such, however, that the strata vary from point to point. Frequently the coarser stratum in one limited area appears to have

*"Subsurface Water Supply of Western Long Island and Its Utilization." William F. Laase. *Municipal Engineer's Journal*, 1934.

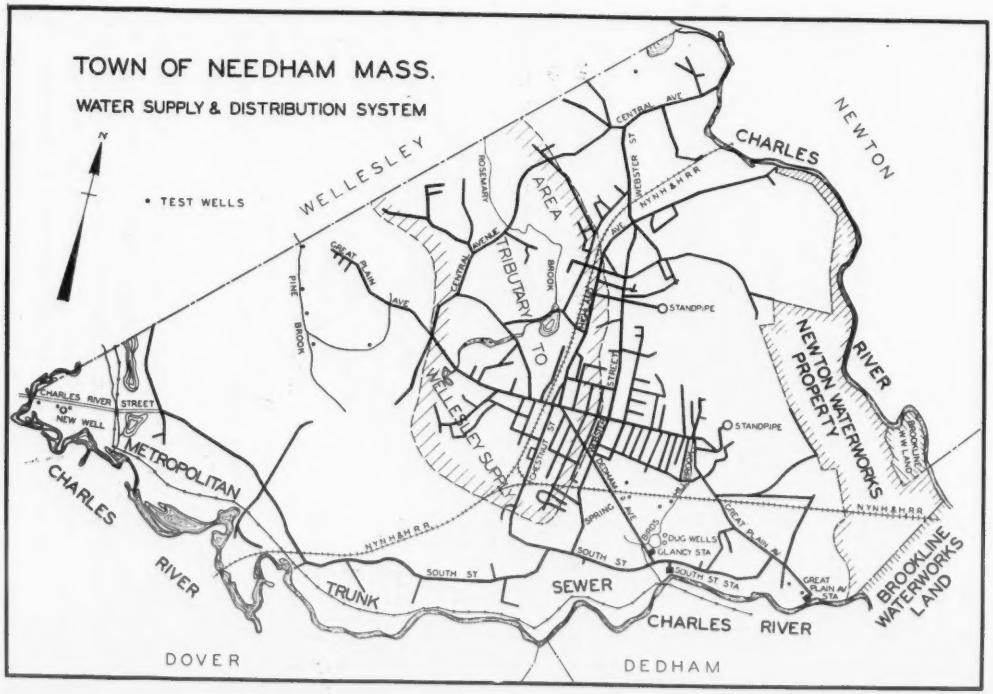

TOWN OF NEEDHAM MASS.
WATER SUPPLY & DISTRIBUTION SYSTEM
N
• TEST WELLS
WELLESLEY
NEWTON
CHARLES
RIVER
AREA
TRIBUTARY
TO
WELLESLEY SUPPLY
CENTRAL AVE
WEBSTER ST
NYNH&HRR
ROSEMARY BROOK
GREAT PLAIN AVE
PINE BROOK
CENTRAL AVENUE
STANDPIPE
STANDPIPE
NEWTON WATERWORKS PROPERTY
BROOKLINE WW LAND
CHARLES RIVER STREET
NEW WELL
METROPOLITAN
CHARLES
RIVER
TRUNK
SEWER
NYNH&H R.R.
SOUTH ST
SPRING AVE
DOUG WELLS
GLANCY STA
SOUTH ST STA
GREAT PLAIN AV STA
BROOKLINE WATERWORKS LAND
CHARLES RIVER
DOVER
DEDHAM

FIG. 2.

no connection with a similar layer in an adjacent area. Even the best methods of sampling materials encountered in test boring leave us in the dark as to the exact nature of a very thin layer of coarse material from which all of the fines have been washed by the passage of water between two lenses of coarse sand, and since the hydraulic capacity of such a coarse stratum may be one hundred or more times that of an equal thickness of the finer material above and below, its importance in our natural collecting system can easily be realized. Furthermore, no matter how closely the borings are spaced, the connecting links may be missed entirely. Examination of hydraulic fills in the making or of the flow of water over earth slope reveals the tendency to form channels which will continue to be important aquifers with just sufficient coarse material to support any earth deposited above. The importance of such small connecting aquifers to our New England ground water resources can not be over-emphasized. To return to our analogy, they can be likened to the channels between reservoirs or lakes from only one of which water is drawn directly, but all of which respond to such draft.

Type of Well. The type of well that will best collect the waters from such underground storage depends on the depth and nature of the water-bearing strata and the desired draft. If the only important aquifer that may be available within the area is thin and lies over relatively impervious material, it is obvious that continuous pumping from a single well is not the answer, but that the water must be collected from many points in the permeable stratum. On the other hand, if there is a deep deposit of coarse material to serve as a local reservoir and also as a collecting agency to bring in water not only from more distant permeable deposits, but also by seepage from the less permeable beds of fine material around its large perimeter, it is possible to draw large volumes of water continuously. Under such conditions, the problem becomes that of constructing a well that will utilize the available hydraulic capacity of the deep coarse stratum with flat hydraulic gradients and easy access to the pump. Such a condition was found to exist in Needham.

Test Wells. Test borings had first been made in various other parts of the town in the valleys of brooks that had sufficient drainage area to supply the needed draft but without discovering material from which the water could economically be collected. These areas were nearer to the distribution system or for other reasons warranted investigation before testing the most promising area in the main valley of the Charles River, near the southwesterly corner of the town. When this was done, there was found eighty to one hundred feet of depth above the rock floor, most of the material being coarse, although there were variations from point to point, both horizontally and vertically. See Figure 2.

Nature of Material. The sieve analysis shown in Figure 3 records the nature of the deposit at the site selected and was in fact made after the well was excavated, using material removed from the caisson by the con-

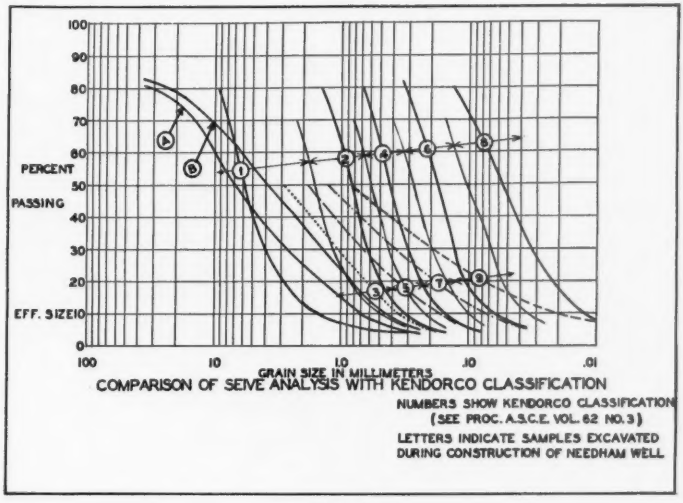

PERCENT PASSING
EFF. SIZE
GRAIN SIZE IN MILLIMETERS
COMPARISON OF SEIVE ANALYSIS WITH KENDORCO CLASSIFICATION
NUMBERS SHOW KENDORCO CLASSIFICATION
(SEE PROC. A.S.C.E. VOL. 62 NO. 3)
LETTERS INDICATE SAMPLES EXCAVATED
DURING CONSTRUCTION OF NEEDHAM WELL

FIG. 3.

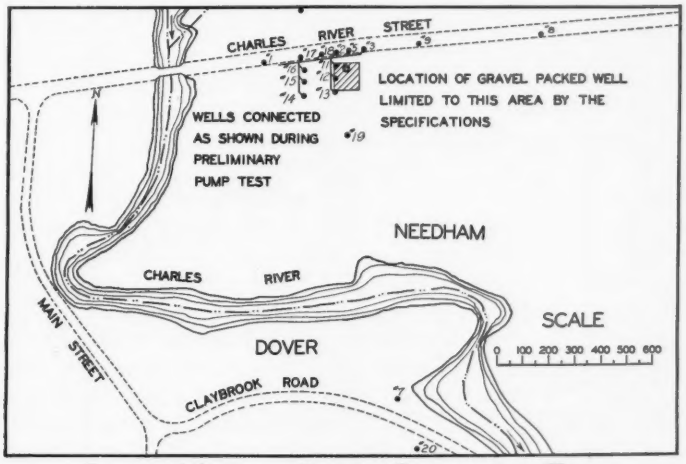


FIG. 4. — LOCATION OF NEEDHAM GRAVEL-PACKED WELL.

tractor in his operations. Although fines were unquestionably washed out by the excavation methods and the samples analysed do not truly represent the natural undisturbed condition, they are believed to do so more nearly than do washed samples from test borings. The water was not being pumped

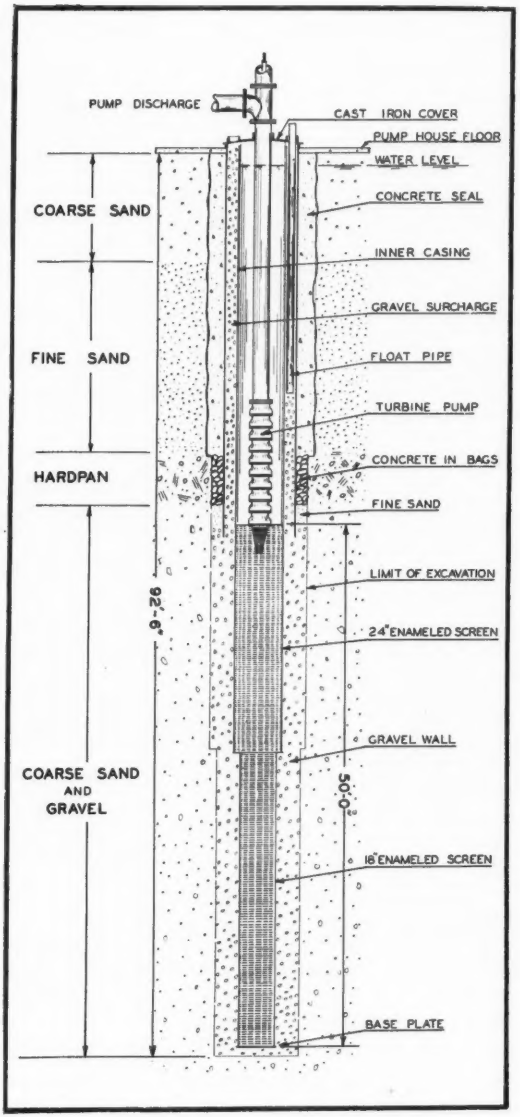


FIG. 5. — SECTION THROUGH NEEDHAM GRAVEL-PACKED WELL.

from the caisson during construction, and the material excavated by orange peel and mud bucket was dumped in a spoil bank alongside the work, the samples being carefully selected in an effort to make them truly representative. Comparison with the Kendorco Classification and the permeability of the different classes of materials listed by Dore* shows the exceptionally favorable hydraulic capacity of the deposit which serves both as reservoir and channel leading to the well and pump. It should be noted that the Quabbin dams investigations of the Metropolitan District Water Supply Commission of Boston showed a permeability of 15 for Class 3 (coarse sand, variable) with a porosity of only 25 per cent., as compared with a permeability of only 0.15 for Class 8 (rock floor, uniform) with a porosity of 41 per cent. In other words, although sixty per cent. more water is stored in a given volume of Class 8 material, the flow through such material under uniform conditions of ground water slope and temperature is only one per cent. of that to be obtained through the voids of Class 3 material. The effective size of the Needham material, as shown by the analyses, lay between Classes 1 and 3, and we might expect the permeability to be between 200 and 300, an extremely high value, but borne out by later figures.

Gravel-Packed Well Selected. When test wells had disclosed the nature and depth and something of the extent of the coarse deposits, ten of them were connected and pumped at 530 g.p.m. for two weeks. The draw-down was small and recovery rapid, which facts, coupled with the known watershed area, made it evident that a satisfactory yield could be secured. In order to utilize the favorable depth of coarse material for admitting water to the well, it was decided that this should be of the gravel-packed type, not less than 60 ft. in depth and as much deeper as necessary or desirable to limit the draw-down. Specifications required the well to be located within a square one hundred feet on a side and named minimum figures not only for depth and diameter of well but also for length and diameter of screen. See Figures 4 and 5. Bidders were permitted to examine all records of test borings and preliminary pumping tests and to drive other test wells if they chose to do so. They were required to give in their bid a draw-down when pumping at a rate of 1-m.g.d. This figure was taken into account at the rate of three hundred dollars per foot of draw-down, not only in comparing bids but also in figuring a bonus or penalty in the final payment. This gave an inducement to the contractor to make the well deeper and freer-yielding than might otherwise have complied with the specifications.

Bonus Earned. The Layne-Bowler Company of New England was awarded the contract on its bid of $8 000 and five-foot draw-down and earned the maximum bonus of $600 permitted under the specifications. In order to avoid penalty and make as spectacular a success as possible,

*See Permeability Determinations, Quabbin Dams. Stanley M. Dore, Proc. A.S.C.E., March, 1936.

this Company exceeded the strict requirements of the specifications, constructing the well deeper and with more and larger screen than was required, with the result that the draw-down on the official test was only 2.6 ft. when pumping at 700 g.p.m. Later pumping at very much higher rates, limited only by the pump capacity available, gave proportionately greater draw-down, but at no time was there evidence of any measurable loss of head between points immediately outside and the water in the well itself. On the contrary, there was a gentle slope in all directions toward the well, so far as could be determined from the observation wells read throughout the test periods and from the observations which have continued during operation.

Equipment. Study of rates, efficiencies, dependability and all factors of the problem resulted in the taking of bids on Diesel engines, turbine pump and appurtenances. Although new and lower electric rates were offered, the Diesel power was found to be more economical. The contract for the equipment was awarded to Fairbanks-Morse and Company upon its capitalized bid, taking into consideration the guaranteed efficiencies of engine, gear and pump. The official test of the equipment showed that the guarantees had been exceeded and that the pumping cost, with fuel oil at 5c per gal., was only $3.95 per m.g., when pumping against 272.5 ft. of head at a rate of 702 g.p.m., and only $5.85 when pumping the same quantity against 309.3 ft. at a rate of 349.5 g.p.m. Because of the limitations imposed by sizes of some of the mains in the distribution system between the new supply and the center of the town, it is not desirable to increase the pressure sufficiently to pump at the higher rate. The head-capacity characteristics of the 12-in., 13-stage turbine pump are such that, as new mains are added, the rate of discharge will increase to the desired quantity.

Pump House. The building housing the engine and equipment is of Colonial architecture, 18 by 27 ft. in plan. In the basement, of reinforced concrete, are the discharge piping, heat exchanger and starting equipment. The superstructure is of brick, with salt-glazed tile interior and quarry-tile floor. The 75-h.p., single-cylinder engine is centrally located and drives the pump through a Farrel-Birmingham bevel-gear speed-increaser. Because many data about the well, equipment and pump house have already appeared in engineering publications,* they will not be repeated here. The plant is not automatic but has all necessary protective devices. It has operated continuously since early in February, 1937 with the exception of a shut-down of a few hours in May for inspection. Since February, it has operated unattended except for six visits per day for the purpose of replenishing the day fuel tank and a general check-up.

Draw-Down. The draw-down in a well is made up of two factors; the depletion of storage and the creation of slope to cause flow. The first may

**Water Works Engineering*, December 9, 1936 and *American City*, July 1937.

be almost entirely local, as in the case of a large-diameter well from which intermittent pumping for a few hours at a time does not withdraw enough water to create a slope sufficient to induce a flow equal to the draft. On the other hand it may be largely depletion of storage in the ground around the well. As may be seen, depletion of storage is accompanied by the creation of a slope: the first case cited resulting in a slope that will increase with the duration of pumping, finally reaching a fairly uniform condition such that the flow into the well equals the draft; the second condition being met when draft exceeds replenishment in the porous material serving as a reservoir. When this latter condition exists, the total draw-down, measured from original level, increases until the supply is insufficient to permit continued draft or until the zone of influence, or limit of the slope created by the draft, reaches new areas from which water can flow freely. Examples of these conditions are met in dewatering excavations.

Slope. Similarly, the creation of a slope results in depletion of storage, at least to the extent of the volume of water withdrawn from the "cone of depression." If the water surface, as disclosed by observations in the well and at points at varying distances from it, soon reaches a fixed shape and general level which is maintained in spite of continued pumping, we may assume that our local "reservoir" is being replenished by an inflow equal to the draft. The slope of the water surface as it flows toward the well is a gage of the hydraulic capacity of the permeable material and depends upon the permeability coefficient and the area of the cross-section. The slope varies from point to point, increasing with the ratio of quantity flowing to area of cross-section through which it flows so that with uniform depth of permeable deposit the maximum slope is reached at the periphery of the well. With some types of well, there is a distinct friction loss in entrance, but when the outer wall of the well consists of gravel, the permeability of which is far greater than that of the earth itself, the friction loss at this point becomes very small.

Effect of Slope. The effect of the slope and of the factors of which the slope is an indication are such that every effort should be made to keep this slope a minimum. The best way to accomplish this is by persistent and thorough underground exploration to locate a deep deposit of coarse sand and gravel, in back of which there is a satisfactory watershed, and then to construct a well that will utilize the full hydraulic capacity of that permeable stratum. To do less, when a high-capacity well is required, is to increase pumping head, cut down the cross-sectional area available for flow,— thus further increasing the slope and draw-down,— and limit the useful life of the well by overdraft. At Needham, the total draw-down, when pumping at a rate of 1 m.g.d. for which the well and plant are designed, was 2.6 ft., measured from the original static level in the well. During the demonstration pumping period, when a pumping rate of 4.5 m.g.d. was maintained during the day and evening, the limit of draw-down

for the rate was not reached, 8 ft. being the maximum recorded, but the shape of the time-draw-down curve indicated that continuous pumping would have resulted in a draw-down of 11 or 12 ft. and a gradually flattening slope which would become tangent to the normal water table several thousand feet away, beyond the area covered by observation wells. The farthest observation well during the preliminary tests was No. 7, on the south side of the river and about a quarter mile from the location selected for the gravel-packed well. This well was later pulled and replaced by No. 20, slightly farther from the river and about 1 450 ft. from the main well. Both of these observation wells responded to any pumping rate that was continued long enough to establish the hydraulic slope. Between these wells and the gravel-packed well, the difference in elevation of water surface, under draft, was found to be nearly 2 ft. p.m.g. per day.

Comparison with Quabbin Dams. It is interesting to compare the effect of pumping at the Needham well with that at the Quabbin Dams during construction of the core walls. The watershed areas and depths to rock at the two places are not greatly different but the permeabilities of the glacial deposits around the pumping centers at the dams is much less than that found in Needham. Pumping at an average rate of about 3 m.g.d. at Quabbin lowered the water level by at least double the amount indicated at Needham for a pumping rate 50 per cent. greater. In these figures, there is indicated a permeability of the Needham material at least three times that at Quabbin, without considering the greater radius of the zone of influence and resultant flatter slope that would evidently have been shown if the high pumping rate had been continued and observations made over a sufficient area. The effective size of the samples analyzed is greater than that of any of the Kendorco classifications except No. 1, of which the permeability is more than one hundred times as great as that of medium, variable sand; and since much of the fine material near the well was removed during its development, the effective size and permeability of the remaining material must be substantially increased from what it was originally at this point. A study of the shape of the draw-down curves of the readings taken during the continuous pumping through the Spring and Summer of 1937 permits a determination of the permeability of the materials through which the water flows. This was found to vary between 100 and 300, depending upon assumptions of porosity, and agrees very well with determinations from the sand analyses.

Permeability. The importance of permeability may be understood by all who have ever given any thought to ground water flow, but its effect may not be entirely clear. Two wells, apparently located and constructed to be as similar as possible may differ only in that the effective size and porosity of the surrounding materials is, to casual examination, slightly less favorable in one case than in the other, but the permeability may easily differ by a large enough factor to limit the yield of the less favorable well

to a small fraction of that of the better well. The velocity of flow under similar conditions of depth of stratum and draft, will vary inversely as the porosity of the material, but the permeability increases so rapidly with the effective size, as well as with porosity, that relatively small differences in sand characteristics make a big difference in slope of water surface for a given draft and consequently in potential yield from a given area. For example, a few additional fines in a sand of 0.5-mm. effective size and 35 per cent. porosity can change the effective size to 0.3 mm. and the porosity to 30 per cent. Such a change will result in an increased velocity of only 17 per cent. but will increase the slope of the ground-water by 400 per cent. or more. Conversely, with a given slope,— or in other words, with a given limiting draft,— the yield of the more permeable material will be several times that of the slightly finer and denser sand.

Conclusions. From the results of the investigations before and during the construction of the Needham well and observations of ground-water conditions under continued draft, the writer believes that too much emphasis can not be placed on thorough search for favorable area before deciding upon a water supply. Watershed area is important. Underground storage in large volume is necessary. The most important factor of all, however, if a successful ground water supply is to be found, is the permeability of the material conducting the water to the well. A great deal of credit for persistence in the preliminary search for the area now being used so successfully in Needham should go to Roger G. Oakman, Needham's water superintendent, who was able to persuade the town authorities that such investigation was the best investment they could make. His records of groundwater level and operation data are worthy of attention.

EXPERIENCES WITH LOW-VELOCITY GRAVEL-PACKED WELLS.

BY PAUL F. HOWARD.*

[*Read September 23, 1937.*]

Attleboro, Mass. The city of Attleboro, Mass., being in need of an additional water supply employed, in 1922, an engineer to make a study of available water resources. In the fall of 1924, fourteen test wells and three observation wells were driven on the west side of Wading River just north of Balcom Street in the town of Mansfield, and a pumping test was made. The data of this test show that continuous pumping was started October 2, 1924 at a rate of 400 000 g.p.d. and the test continued at this rate until October 15. The significant point in connection with the test was that the water table continued to be lowered in the ground during pumping at the rate mentioned and that it sank at a more rapid rate when pumping was increased to a rate of 600 000 g.p.d. This indicated that the area immediately tributary to these wells would not continuously yield water at these rates of pumping. This considerable draw down during the pumping test was confirmed by a later survey of conditions, made by Whitman & Howard during their investigation in 1934. Analyses of the water made during this first test in 1924 showed that it was satisfactory in all respects, its iron content amounting only to 0.15 p.p.m.

Following the pumping test, the water supply system was constructed in 1929 and 1930 at a total cost of about $370 000. The works consisted of 88 driven wells constructed of 2½-in. iron pipe, the wells varying in depth from 20 to 32 ft. These wells were connected in the usual way with 2½-in. connections to cast-iron pipe suction mains. The pumping equipment installed consisted of two centrifugal pumps, one with a rated capacity of 1.5 m.g.d. and the other with a rated capacity of 2.5 m.g.d. These pumps were so arranged that they could both be operated at the same time. They were connected to a stand-by gasoline engine capable of driving either pump alone or both at the same tine. Water pumped into the mains was measured by a Venturi recording meter and piped to Attleboro by means of an 18-in. cast-iron force main about 4½ miles long.

As previously stated, the water from the test wells during the pumping test in 1924 was of good quality. Undoubtedly the water was equally favorable in quality when the 88 wells for a supply for the city of Attleboro were driven in 1929. After being placed in use, however, the quality of this supply deteriorated rapidly, as shown by State Department of Health analyses, and the water was unsatisfactory owing to the large amount of iron present. During 1930 to 1934 the iron content of the water varied from 0.98 to 1.94 p.p.m.

*Consulting Engineer, Whitman & Howard, Boston.

In 1934, during lengthy studies of this supply by the author's firm, an examination was made of each well in the well field, and samples were taken for analysis. Tests were made by means of a special device developed by us for this purpose, known as a well-rater and sampler, a description of which has been given by the author in a previous paper* before this Association. It was found by these tests that the amount of iron in the water coming from each well under actual operating conditions varied from 0.04 to 6.0 p.p.m. and averaged 1.21 p.p.m. It was also found that the wells in the vicinity of the original test wells yielded water containing the least amount of iron but that the wells that produced water containing an objectionable amount of iron were in the majority and scattered so that a policy of discontinuing the use of certain wells and pumping from the remainder was not worthy of adoption.

The tail pieces of pipe for each well had 5 rows of $\frac{3}{8}$-in. holes and an open end. Hence the 88 wells connected to the suction main to draw water from the well field had a combined entrance area or opening for the admission of water of 4.9 sq. ft. Pumping water from the wells at a rate of 1.5 m.g.d., as was often done, produced an average entrance velocity of 81 ft. per min. on the assumption that the soil in the field had an average porosity or open space of about 35 per cent.

During our study, the quantity and quality of water obtainable from each individual well was determined while pumping into the mains with the small pump in the pumping station at a rate of 608 000 g.p.d. The average volume from each well during the test was 5 g.p.m., but yields from individual wells varied from 1 to 25 g.p.m., showing that the burden on the wells was unevenly distributed. This test showed also that the entrance velocity of the water into the well yielding 25 g.p.m. could be estimated at about 175 ft. per min., or five times as great as the velocity for the average well.

The water drawn from the ground when the 88 driven wells were in use flowed into the wells through an entering area of only 4.9 sq. ft., as previously stated, and was brought into the wells in such a way that the suction lift varied from 6 to 22 ft. This was due to the fact that the pumps were of such type and capacity that they were operated only during a few hours daily. The method and rate of pumping were, to a large extent, responsible for the fact that the iron in the supply increased so rapidly above that shown by the test of 1924, that is to say, conditions were encouraged in the ground through which the water came to the wells that caused, in the author's opinion, exhaustion of free oxygen in the water and reduction of non-soluble iron oxides to a soluble form.

It was decided that, in order to obviate all of these adverse factors, several changes in the system were necessary. First, that the fine top soil over-lying the sand and gravel of this area, to a thickness of about 20 in., should be removed. This fine material contained much iron and probably added iron to the water supply by the rain collecting upon it percolating

*This JOURNAL 50, 219 (1936).

through and taking iron into solution. Second, that low-velocity, gravel-packed wells into which water would enter at a rate of not over 2½-in. per min. as distinguished from an estimated average rate of flow into the driven wells of 67 ft. per min. should be constructed. We believed that wells of this type with slow entering velocity would yield water always containing free oxygen and that there would be no reduction of the iron oxides to soluble forms. Third, that the method and rate of pumping should be changed in order that too great a volume of water would not be drawn from this field during any day. Fourth, that to increase the water supply the area should be flooded with water from the mill pond just above the area by means of the canal flowing past this area. To do this successfully, it was also recommended that the material removed from the upper portion of this area be so placed as to form a dike which would hold the water from the canal on the area or well field for percolation.

In the fall of 1935, the city voted to carry out a portion of the plan recommended by us, and a contract for the work was awarded to C. Reppucci & Company of Boston and satisfactorily completed. This firm stripped the surface material from two acres of the Wading River well field and built dikes around these two acres with the stripped material. They also constructed, according to our plans, three specially designed, low-velocity, gravel-packed wells varying in diameter from 52 in. at the bottom to 64 in. at the top and averaging 22½ ft. in depth. Pipe lines together with valves and concrete head walls were built in order that the area might be flooded or not, as desired. This plan was entirely based on our belief that satisfactory water, low in iron, could be pumped from this area, by changing from the 88 small, high-velocity, driven wells into which water was drawn under unfavorable conditions of velocity of flow and high rate of pumping, to these low-velocity, gravel-packed wells from which the water should be pumped at a uniform low rate. It was also believed by us that the quantity of water could be augmented and its quality perhaps improved by flooding the stripped area around the wells. Pumping tests showed that our theories and beliefs were well founded and correct.

Two pumping tests were made of the reconstructed supply. During the first test, lasting from December 16, to December 24, 1935, ground water alone was pumped. During the second test from December 27, 1935 to January 4, 1936, the area was flooded and a mixture of ground water and filtered surface water was pumped. The results of these tests are given in the following. During the first test, the rate of pumping was 100 g.p.m. from each well or a total of 432 000 gal. per day of 24 hours from the three wells. During the first test, water in the new wells was lowered 4 ft. After the test was stopped, the water level recovered 2 ft. at once and had completely recovered in two days. During this test, the bacterial condition of the water was declared satisfactory by the State Department of Public Health, and the chemical analyses of the water made by that department showed that its quality was entirely satisfactory. The water was low in iron, the iron content averaging 0.2 p.p.m. during the last three days of the

test. During the second test, *i.e.*, with the area flooded, water was pumped at the same rate as during the first test. It was also of good quality bacterially and chemically, as shown by State Department of Public Health analyses. The iron content during the last three days of the test averaged 0.15 p.p.m.

During the following months, the iron content of the water pumped to the city, as shown by State Department of Public Health analyses, averaged 0.15 p.p.m. During this period also, the free ammonia averaged 0.005 p.p.m. and the color 15 p.p.m.

It is worth mentioning that during construction of the three gravel-packed wells, layers of gravel were encountered that were covered with oxides of iron, also stones of all sizes absolutely red with iron on their surfaces; further, a mass of rotten stone having the color of iron rust. However, as the water entered these wells at a low rate, an adequate percentage of free oxygen was always present in this water; hence in the author's opinion no iron was taken into solution. This condition was probably aided to a considerable degree by the removal of fine material from the surface of the area in which these three wells were constructed.

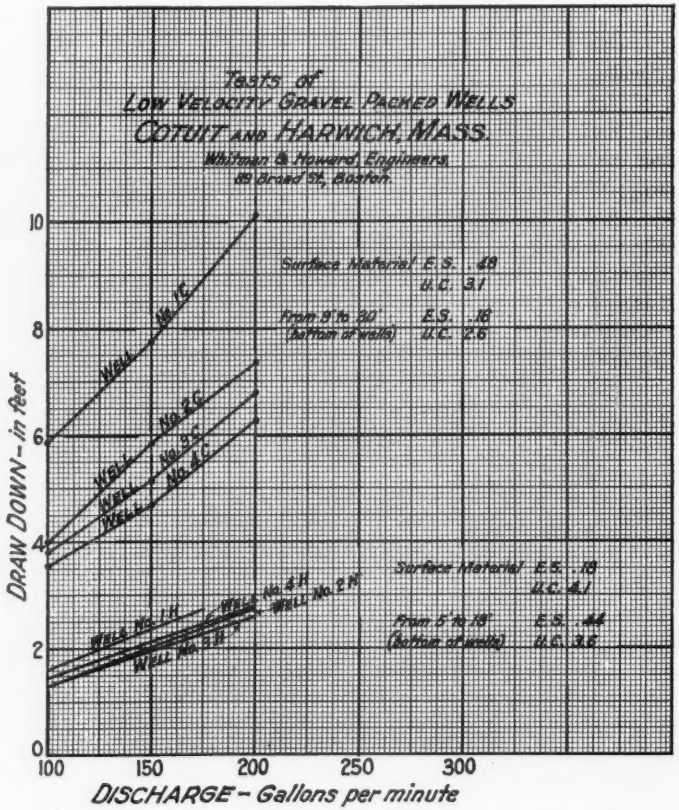
It is also of interest to note that the river water applied to the area is fairly highly colored and contains, at times, considerable iron. Notwithstanding the presence of iron in connection with organic matter, the rate of flow through the ground to the wells is so low, and the distance which most of this water travels to the wells so great, that in the author's opinion ample opportunity is given for the oxidation and removal of both iron and organic coloring matter.

The results of the work upon this portion of the well field and the results of the pumping test and analyses made indicate that if the entire area were developed by this method, a larger and equally satisfactory water supply could be obtained.

Cotuit, Mass. During the spring of 1936, the Cotuit Fire District, situated in the town of Barnstable, Mass. on Cape Cod, installed in accordance with plans by the author's firm, a new water system. In developing this supply, nine 2½-in. pipe test wells were first driven to depths varying from 30 to 40 ft. These test wells showed that there was a somewhat tight stratum of fine sand between depths of 30 and 33 ft. The water removed from below this stratum by means of the pipe test wells contained an excessive amount of iron, while the water from above the stratum was entirely satisfactory. This meant that the wells should not be constructed to a depth greater than 30 ft. As some water would probably be drawn through the rather tight stratum of fine sand, it was decided to install four gravel-packed wells. These wells (200 ft. apart, 52 in. in diameter and 30 ft. deep) are of the low-velocity type. In the author's opinion this serves as a further precaution against the occurrence of an objectionable amount of iron in the new water supply.

Their construction is similar to that of the Attleboro wells at Wading

River. Two of them were tested by means of a pumping test lasting eight days at an average rate of pumping of 345 000 g.p.d. During this test, the level of the water in the observation pipe in one well dropped 5 ft. and in the other 5.7 ft. and remained at these levels for the duration of the test. When pumping ceased, the ground water recovered in a short time to within a few inches of its level prior to the start of the test.



The satisfactory yield obtained was expected because the wells were constructed in a large sandy area in which the surface material to a depth of about 9 ft. is clean sand with an effective size of 0.48 mm. and a uniformity coefficient of 3.1. Under this surface material, down to a depth of 30 ft., is a stratum of somewhat finer sand with an effective size of 0.16 mm. and a uniformity coefficient of 2.6.

The relationship of the discharge to the draw down on each of these four wells is shown in the accompanying chart. It will be noticed that,

within the range of observations, the draw-down is practically proportional to the yield.

The water is drawn from the four wells at a combined rate of 500 g.p.m. by means of a Diesel-engine-driven, centrifugal pump located in the nearby pumping station. If needed, a 500-g.p.m. centrifugal pump driven by a gasoline engine, may be thrown into service, making a total combined rate of 1 000 g.p.m.

The water from these wells is satisfactory in every respect and has an average iron content of about 0.18 p.p.m. The wells were constructed by Crandall Inc.

Harwich, Mass. In 1936, the town of Harwich, Mass., situated on Cape Cod, installed a new water system according to plans by the author's office. Eight 2½-in. pipe test wells were driven to a depth of about 35 ft. The water removed from the ground by means of these test wells was analyzed and found to be entirely satisfactory for the purposes of a municipal water supply. As a result, four gravel-packed wells situated 200 ft. apart, and similar to those installed at Cotuit, were built. Two of them were tested by means of a pumping test, lasting six days, at an average rate of pumping of 275 000 g.p.d. During this period of pumping, the level of the water in each observation pipe placed in the large wells dropped only 1 ft. 9 in. and remained at that level for the duration of the test. When pumping ceased, the ground water recovered almost immediately to its original height.

These wells were constructed in a large sand valley. The top sand, generally speaking, has an effective size of 0.18 mm. and a uniformity coefficient of 4.1, while the under-lying stratum of sand, 5 to 18 ft. thick above the bottom of the wells, has an effective size of 0.44 mm. and a uniformity coefficient of 3.6. This coarse, uniform sand accounts for the large yield and low draw-down of these wells. As in the case of Cotuit, the relationship of discharge to the draw-down on each of these four wells, as shown by the accompanying chart, was proportional to the yield within the range of observations. Each of these wells will yield water at a rate of 1 m.g.d. for a 9 ft. draw-down.

The water from these gravel-packed wells is satisfactory in every respect and has an iron content of about 0.09 p.p.m.

Water is ordinarily drawn from the four wells at a combined rate of 500 g.p.m. by means of a Diesel-engine-driven, centrifugal pump located in the nearby pumping station. However, if needed, the water may also be drawn by a 500-g.p.m. centrifugal pump driven by a gasoline engine, making a total combined rate of 1 000 g.p.m.

The wells were built by C. Reppucci & Co.

ADDITIONAL GROUND WATER SUPPLY FOR WOBURN, MASS.

BY JOHN P. WENTWORTH.*

[*Read September 23, 1937.*]

History of the Water Supply of Woburn. The water supply of Woburn has been obtained, ever since the works were built in 1873, either from wells and filter galleries located adjacent to Horn Pond at its southerly end or, at times, directly from the pond.

Horn Pond is situated in Woburn near its southerly boundary, about half-way between the easterly and westerly limits. It has a surface area of slightly more than 100 acres and receives run-off from a drainage area of 7.5 sq. miles. A small portion on the easterly side of the drainage area includes a part of the most densely settled district of the city of Woburn. The remainder of the drainage area contains a considerable amount of rough and rocky land, covered to a considerable extent by a scrub growth; appreciable areas of swampy land; and a material amount of highly-cultivated farm land.

The first supply was taken from a filter gallery, parallel to the southerly shore of the pond at a distance of about 80 ft. from it. See Figure 1. This gallery was 82 ft. long, and the bottom was about 10 ft. below the high-water level of the pond. A connection for emergency use was made to the pond. In 1908, a new suction well, 20 ft. in diameter, was dug at a distance of about 80 ft. from the westerly end of the filter gallery. The bottom of the well was 10 ft. lower than the bottom of the filter gallery. In 1909, fifty 2½-in. driven wells were put down near the westerly shore of the pond, about 1 500 ft. distant from the suction well. The depth of these wells ranged from 25 to 64 ft. and averaged 45 ft.

As the yield of the filter gallery and wells decreased and the water consumption increased, it became necessary to use raw water from Horn Pond. Since it was realized that the hazard of using raw water from the pond was becoming greater each year, a gravel-packed well was constructed in 1927 about 300 ft. easterly from the old filter gallery. This well was 40 ft. deep and yielded about 0.75 m.g.d. It was constructed by the Layne-New York Company and is known as the Layne well or Well A.

In 1931, the city entered into a contract with P. D. Bowler to furnish an additional supply. Mr. Bowler guaranteed a yield of 2.5 m.g.d. in addition to the yield of the Layne well. Three gravel-packed wells, known as Wells B, C and D were constructed near the original water supply works. The depths of these wells are 65, 70 and 57 ft. respectively. Tests on these wells showed a yield of 2.9 m.g.d. in addition to the yield of Well A, or 0.4 m.g.d. above the guaranteed quantity.

*Of Metcalf & Eddy, Engineers, Boston, Mass.

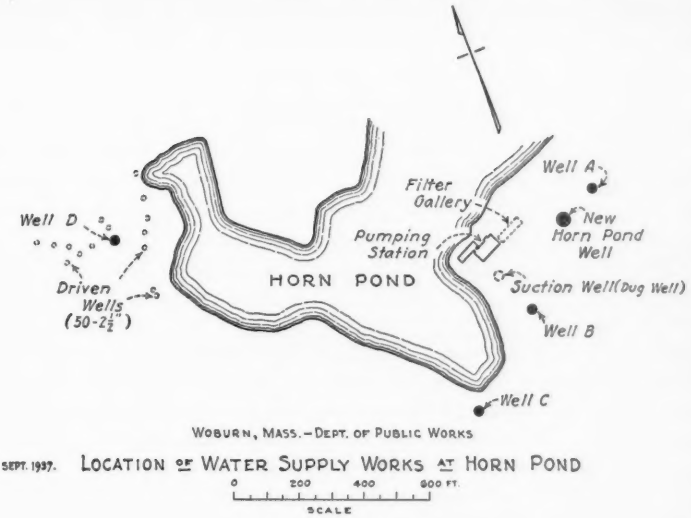


FIG. 1.

Results of Operation of Gravel-Packed Wells. The ability of a ground water supply to maintain its quantity and quality is always problematical and depends on many factors. The following information may be of interest. Although the city was obliged to abandon the filter gallery, dug well and driven wells, the gravel-packed wells, taken as a whole, have been successful. A 21-day test made on the four wells in December, 1931, showed a total yield of 3.3 m.g.d. There has been no recent test covering any considerable length of time to determine the present yield, but on one day in July, 1936, after a period of heavy draft, the four wells were pumped continuously for 24 hours. The yield was 3.1 m.g. in this time.

Well C was constructed in fine sand, and its yield has always been relatively low. Recently fine sand was drawn into the suction pipe, and the well is not in use at the present time.

The quality of water from the gravel-packed wells is practically the same today as when the wells were originally constructed. With the exception of slight corrosiveness, the water is excellent.

Additional Water Supply. In the latter part of 1935, the city decided to proceed with the construction of additional gravel-packed wells as a P.W.A. project. The contract was awarded to the lowest bidder, C. Reppucci & Company of Boston. The work of constructing the wells and pumping stations and of furnishing and installing pumping equipment was sub-let to P. D. Bowler and the New England Water Supply Corporation.

The contract was a modified form of the so-called "no water — no pay" contract. In the usual form of this type of contract, the contractor

receives no pay unless he produces a certain amount of water of specified quality. In this case, however, payment was to be made for exploratory work, pipe lines, etc., regardless of the quality or quantity of the water. The payment for the principal item, which included the wells, pump houses and pumping equipment, depended upon the contractor's ability to produce a certain quantity of water, the quality of which must be acceptable to the State Department of Health. Payment for this item was on the basis of a unit price for each million gallons daily of yield. The quality and quantity of water were guaranteed for a period of one year.

The contract specified that a supply of not less than 2 m.g.d. should be furnished and that payment would not be made for a greater quantity than 3 m.g.d. No single well would be accepted which yielded less than 0.5 m.g.d. The contract called for a 21-day acceptance test of the completed wells, to determine the quantity and quality of the water. Upon the results of this test depended the quantity of water for which the contractor was to be paid. If he was of the opinion that, because of especially favorable conditions during the acceptance test, the quantity of water yielded by the wells was greater than he cared to guarantee, he could so state in writing, stipulating what quantity of water he would guarantee. The acceptance tests showed a yield of 4.1 m.g.d., but the contractor guaranteed a yield of 3 m.g.d., the maximum amount for which he could receive payment.

The contract drawings showed six locations in which the contractor might develop a new supply. These locations were in various parts of the city, but there was none shown in the vicinity of Horn Pond. According to the contract, other locations could be used, subject to the mutual consent of the city and the contractor. Three of the six locations were disapproved by the State Department of Health. Test wells were put down in the three remaining locations and in several other locations, but a satisfactory supply was not obtained in any of them. It was quite apparent that a suitable supply could not be found in Woburn outside of the vicinity of Horn Pond. One reason for this is the fact that a large part of Woburn lies in the drainage area of a branch of the Aberjona River. This area contains several large industrial establishments. The river is polluted at times, and a large sewer passes through the water-bearing land. The ground-water supply in this area has been highly developed for industrial use.

The next step was to explore further the land in the vicinity of Horn Pond. In several sections there was a high amount of iron in the water, but two locations were found which appeared to be satisfactory, one near the old Horn Pond pumping station and the other near Lexington Street. Permanent gravel-packed wells were constructed at these sites and will be referred to as the Horn Pond Well and the Lexington Street Well. The latter is about half a mile north of the north shore of Horn Pond.

Construction of New Wells. Both wells are the of gravel-packed type. At the Lexington Street site a steel casing was driven to a depth of about 40 ft. below the surface of the ground. The upper portion of the casing

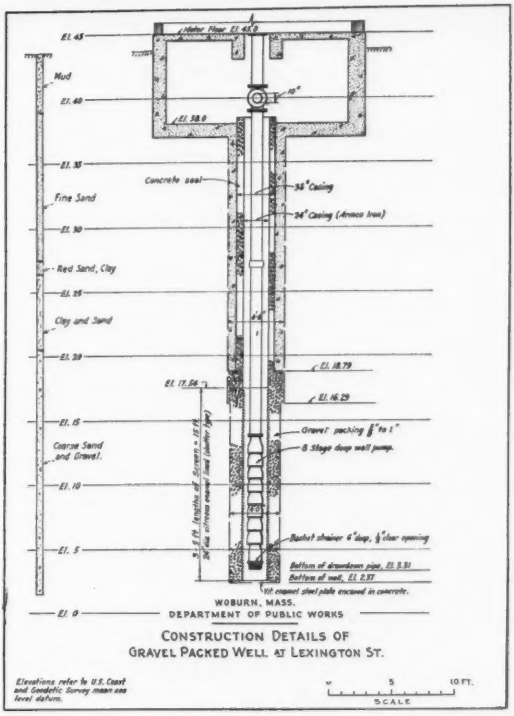


FIG. 2.

was 54 in. in diameter and the lower portion 48 in. in diameter. As the casing was driven, the material within the casing was removed by means of a hydraulic bailer and an orange-peel bucket. After all the material had been removed from within the casing, a 24-in. casing was placed inside the larger casing. The upper 25 ft. of the inner casing was of Armco iron and the lower 15 ft. was composed of screens. In the lower 16 ft. of the well, the space between the inner and outer casings was packed with gravel and the outside casing was pulled. In the upper portion of the well a 36-in. casing was placed between the 24-in. casing and the outside casing. The space between the inner, or 24-in. casing, and the middle, or 36-in. casing, was packed with gravel. The space between the middle and outer casings was filled with concrete, thus producing a cut-off seal. The bottom of the well was sealed by means of an enameled steel plate, encased in concrete. See Figure 2.

The pump house was then constructed. The pump and suction pipe were placed in the well, and the motor and electrical equipment were then installed. A seal was made at the top of the well by welding a steel plate to the top of the 54-in. casing. This plate had an opening for the discharge pipe, and the space between the plate and the pipe was calked with lead.

In order to determine the elevation of the water in the well, a small pipe was placed inside the inner casing, extending nearly to the bottom of the well. At the motor-room floor, an ordinary bicycle pump was connected to the small pipe. A pressure gage calibrated in feet was placed on the pipe. When the determination of water level is made, the water is forced out of the pipe by means of the pump. The gage then shows the height of water above the bottom of the small pipe.

The Horn Pond well was constructed in a manner similar to the Lexington Street well. See Figure 3.

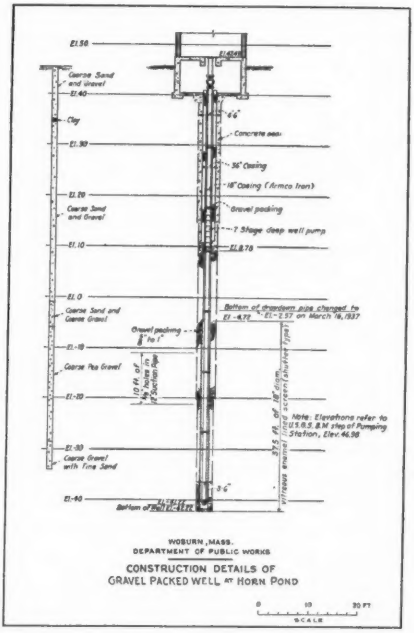


FIG. 3.

Two of the important parts of a gravel-packed well are the gravel packing and the screen. At Woburn, where the ground around the new wells contained no fine material, the question of the gravel packing was not as serious as in other places. Samples of gravel from several pits were tested, and finally a pit located about five miles from the site was chosen. The gravel varied in size from $\frac{5}{8}$ to 1 in. In some localities where fine sand is encountered, a great deal of care must be exercised in the selection of the size of gravel. In some cases it is advisable to make the structure similar to a filter. Very fine gravel or coarse sand is placed next to the natural ground and coarse material is placed around the inside casing. It is necessary to

use additional casings during construction to separate the various sizes of gravel.

The screen section of the wells is the Layne shutter-type screen, made by Layne and Bowler, Inc., of Memphis, Tennessee, and is made of 3/16-in. Armco iron, with openings about ¼ in. in least dimension and with two-coat porcelain enamel coating applied by the Bettinger Enamel Corp. of Waltham, Mass. The screen was built in sections limited to 5-ft. lengths (due to facilities for the porcelain enamel coating.)

Pumping Equipment. At the Horn Pond Well, the pumping equipment consists of a Fairbanks-Morse 7-stage turbine pump operated by a Fairbanks-Morse 150-h.p. vertical, variable-speed motor. Four different speeds were provided. Under normal conditions of ground water the following conditions of pumping can be obtained:

Low or first speed.....	1.8 m.g.d.
Second speed.....	2.2 m.g.d.
Third speed.....	2.5 m.g.d.
Full or fourth speed.....	2.9 m.g.d.

At the Lexington Street Well, the pumping equipment consists of a Byron Jackson 8-stage turbine pump operated by a General Electric 75-h.p. vertical, variable-speed motor. Four different speeds were provided as in the case of the Horn Pond pumping equipment.

The pumping equipment at both locations showed overall efficiencies of slightly over 75 per cent. during the acceptance tests.

Electric Power. The four gravel-packed wells constructed previous to 1936 are operated by 4 000-volt electric current measured by one master meter. The average cost of power during the year 1935 was 1.27 cents per kw.-hour and during the year 1936, 1.28 cents per kw.-hour.

The wells are located very close to an Edison sub-station, and the reliability of service is excellent. In the case of the new Horn Pond Well, it was obvious that this well should be operated by electric power and the current should be taken through the same master meter as for the older wells.

In the case of the new Lexington Street well, consideration was given to the question whether it should be operated by electric current fed through a line from the master meter at Horn Pond or from a separate line from Lexington Street. Because of a likely delay in obtaining land for a transmission line from the master meter, and in order to have current available if the power failed at Horn Pond, it was decided to supply this pump house from the Lexington Street power line, although the cost for current will be considerably greater.

Yield of New Wells. During the 21-day acceptance test on the Horn Pond Well, water was pumped at first at a rate of 2.5 m.g.d. and then increased to 2.7 m.g.d. The ground-water level was stabilized at the end of the test, with a total draw-down of 16 ft. The equivalent yield was 117 g.p.m. per foot of draw-down. At the Horn Pond Well, the rate of pumping was 1.4 m.g.d. and the draw-down 15 ft. The equivalent yield was 65 g.p.m. per foot of draw-down.

Quality of Water. Exploratory wells put down in the vicinity of the old Horn Pond pumping station showed that the character of the water was somewhat different from that of the water from the older wells. In order to determine the quality of the water at different depths, another exploratory well was put down and samples were taken at different depths as the driving progressed. The results were as follows:

Depth Feet.	Temperature °F.	Dissolved Oxygen.		pH	Carbon Dioxide, p.p.m.	Hardness, p.p.m.
		p.p.m.	Saturation, Per cent.			
30	57	2.40	20.6	6.8	17.1	76
40	55	5.80	54.7	6.8	16.6	82
50	54	4.10	37.9	7.0	13.0	90
60	53	1.50	13.7	7.2	8.6	90
70	52	2.20	19.9	7.4	6.4	92
80	..	....	....	7.4	5.9	102

At the Horn Pond permanent well, samples of water taken during the 21-day test showed a hardness of about 95 p.p.m., carbon dioxide equal to 15 p.p.m., a pH of 6.9, and iron to the content of 0.02 p.p.m. Bacteria averaged about 5 per cc., and tests for bacteria of the colon-aërogenes group were negative in all samples.

At the Lexington Street Well the hardness was about 60 p.p.m., carbon dioxide 23 p.p.m., the pH 6.1, and iron 0.01 p.p.m. The bacteria averaged about 5 per cc., and tests for bacteria of the colon-aërogenes group were negative in all samples.

Cost. The cost of construction to the city, excluding land, engineering, legal and administrative services, may be summarized as follows:

Exploratory wells	$6,478.25
Pipe lines	3,494.67
Metering and power service equipment at Lexington Street	2,347.31
Power lines	813.58
Permanent wells, including pump houses and pumping equipment	94,000.00
Pumping, preliminary tests	447.50
Pumping, acceptance tests	1,341.85
Miscellaneous	128.18
Total	$109,051.34

SOME OPERATING EXPERIENCES WITH IRON AND IRON COAGULANTS IN WATER TREATMENT.

BY MALCOLM PIRNIE.*

[*Read September 23, 1937.*]

Salts of iron did not enjoy much popularity as coagulants in water purification and were not extensively used prior to the beginning of the last decade. Iron in ground water, even when present as carbonates, caused many sources of water supply to be passed over in favor of stored or filtered surface water. Difficulties experienced in oxidizing ferrous iron into ferric iron were chiefly responsible, because most of the iron present in water sources and commercially obtainable as coagulants was in the ferrous form. Recently, the by-products of chemical processes have offered to the water works field such coagulants as ferric chloride, anhydrous ferric sulphate and chlorinated copperas, the latter a mixture of ferric chloride and ferric sulphate. These ferric salts are now available as coagulants. They are comparable in cost to aluminum sulphate and are valuable additions to the art of water purification.

Properties of Iron Coagulants.

Copperas. Copperas or ferrous sulphate, a bi-product of the iron pickling process, has been commercially available for many years It absorbs moisture readily and often forms a rock-like mass when stored for an appreciable period of time in large bins. It dissolves readily, forming a highly corrosive solution, which may be stored or conveyed in lead-, rubber- or glass-lined tanks or pipes. Recently, specially prepared copperas has been furnished dry enough to be fed satisfactorily through dry-feed machines in small plants, but storage of the main supply in bags or barrels in a dry room is preferable to storage in bins even for this special product. In a large installation, it might be desirable to dissolve the copperas as it is received and to store the solution in specially prepared tanks. In whatever way the solution is made, the ferrous sulphate can be easily converted into a mixture of ferric chloride and ferric sulphate by feeding liquid chlorine into it in the proportion of 1 part of chlorine to 7.8 parts of copperas.

Ferric Chloride. Ferric chloride can be purchased either as a concentrated solution (40 per cent $Fe\ Cl_3$), in lumps or cake and as anhydrous powder. The crystalline forms are readily soluble and the solution may be stored in rubber-, lead- or glass-lined tanks.

*Consulting Engineer, New York, N. Y.

Ferric Sulphate. Anhydrous ferric sulphate $Fe_2(SO_4)_3$ was first produced as a commercial water coagulant by the Merrimac Chemical Company under the trade name of Ferrisul in connection with experiments conducted by the author in coöperation with the Scituate Water Supply Division of the City of Providence to develop a manganese-free, non-corrosive, filtered water. It is a grey, fine, gravel-like substance which does not absorb water rapidly from the atmosphere and can be stored indefinitely in large dry bins. It can be fed through dry-feed machines as conveniently as alum, but does not dissolve readily except in fairly concentrated solution. Equipment designed for handling and dry-feeding alum, therefore, may be used for anhydrous ferric sulphate up to the point where the chemical is to be dissolved. At this point, the dry chemical must drop from the dry feeder into a lead-, rubber- or glass-lined holder into which warm water is introduced at a rate that will maintain a concentration between 40 and 60 per cent., and the solution must be kept agitated by a stainless steel, hardwood, lead- or rubber-covered, or glass paddle. The overflow from the solution chamber may be diluted as required for convenience of feeding it into the water supply. The diluted solution can be conveyed through a rubber hose or rubber-lined pipe to the raw-water conduit. Use of a rubber hose, attached to a glass tube inserted in the raw-water pipe through a standard insertion cock, will prove most convenient for relatively small installations. Entrance of air to the feed lines should be prevented by ball-cock control of the submergence of the feed line connection to the solution-dilution chamber. Air bubbles create a sticky foam which tends to clog the line.

If the plant design does not permit use of gravity feed of the solution, the solution can be boosted by a simple Pyrex glass eductor as manufactured by the Schütte-Koerting Company, a rubber-suction hose being immersed in the solution-dilution tank.

Ferric sulphate or ferric chloride added to water containing dissolved oxygen will react rapidly to form ferric hydroxide over a pH range extending from something less than pH4 to more than pH10. In these circumstances, it is not necessary for alkalinity to be present in excess of that required to react with the acid radical of the coagulant,— as is so essential in bringing about the decomposition of aluminum sulphate,— and highly colored soft waters may be reduced in color from values as high as 200 p.p.m. to values as low as 10 p.p.m. by allowing coagulation to proceed in the presence of an excess of sulphuric or hydrochloric acid. Adjustment of alkalinity may be effected by aeration and the addition of caustic soda or lime, either after more than usually effective sedimentation or after filtration. When manganese is present in the raw water, the pH of the treated water may be raised to a value of 9 or 10 before filtration and cause the precipitation and removal of manganese. The coagulation of soft waters with ferric sulphate at low pH has also been found beneficial in preparing them for boiler feed-water. A substantial reduction in silicates is obtained, and the sulphates needed to control imbrittlement are supplied in large measure, if not entirely, by the coagulant.

In view of these properties of ferric coagulants, it would seem to be of interest to record at this time some of the results obtained in the operation of several water purification plants in which iron salts have been employed as coagulants.

Waters Containing Ferrous Carbonate.

Long Beach, L. I. At long Beach, Long Island, wells tapping the artesian source in the Lloyd sand delivered water containing practically no calcium and magnesium, about 10 p.p.m. of silica, 7 p.p.m. of iron and 40 p.p.m. of carbon dioxide. After experiments demonstrated its practicability, a simple type of treatment plant was designed to remove the iron. Following fine-spray aeration on the roof of the filter house, the water was apportioned to underdrain systems of several filter boxes containing 9 ft. of graded silica gravel through which the water flowed upward to discharge over the front wall of each box in to the clear-water channel. The aerated water was colorless, retaining all of its iron as ferrous carbonate, until it was brought into contact with the surfaces of the gravel in the filters. Here the iron deposited as ferric hydroxide on the gravel surface, freeing some 10 p.p.m. of carbon dioxide which had formerly held it in colorless solution. This carbon dioxide could be expelled from the effluent water by subsequent aeration at low head. However, aeration was not provided on a plant scale because of lack of funds at the time the plant was constructed in 1921. The possible loss of head in the upward-flow contact beds was limited to 3 ft. When this loss had accumulated, a waste valve on the underdrain system was opened, allowing the water, under about 12 ft. of head in the beds, to flow downward through the beds at a rate of about 6 ft. per min. This effectively discharged the bulk of the accumulated iron. The beds were also provided with gutters above the gravel. These carried off wash water applied to the underdrains, in the manner usual in mechanical-filter design, at a rate of rise of 4 ft. per min. This type of wash was used about once a month, following daily use of the down-wash. The normal rate of upward-flow contact treatment was 2 gal. per sq. ft. per min., and produced an effluent containing less than 0.1 p.p.m. of iron. Operation of the first unit was so successful that the capacity of the plant was increased by 75 per cent. in 1923 and operated successfully until it was grossly overloaded and the operating principles were forgotten in subsequent changes of administration.

Stuart, Florida. A similar plant was constructed for Stuart, Florida, in 1927. Wells in the sands and gravels of an upper fresh ground-water bubble produced water containing about 4.5 p.p.m. of iron and calcium and magnesium carbonates giving an alkalinity of 150 p.p.m. The water had little color. A vacuum-pump priming-system was installed to prevent aerated water from returning through the well strainers to the surrounding gravels and sands, as this was believed to have been the cause of rapid

clogging of other wells in the past. Low-lift pumps delivered the well water to fine-spray aerators, and the treatment in all respects was similar to that at Long Beach. When the plant was placed in operation, it did not remove the iron. Finely divided ferric hydroxide passed upward through the gravel beds to the extent of the original iron concentration. It was evident that the presence of a substantial amount of alkalinity in the raw water completed the decomposition of the ferrous carbonate before the water reached the contact beds and that it would be necessary to delay this action until the water could be brought into contact with the gravel surfaces. The nozzles were removed from the aerator, substantially reducing the degree of aeration, and satisfactory operation of the plant resulted immediately. In all the years of its operation, this plant has required no operating costs other than those for power used in pumping and for less than one hour each day of the operator's time to down-wash or wash the contact beds. The wells have not lost appreciably their original capacities. A substantial number of similar plants have been constructed by the Florida Power and Light Company for iron removal in small industrial or domestic ground water supplies.

The operating experiences with these plants for removing iron found as ferrous carbonate in ground water demonstrate the importance of intimate contact of the salt with previously precipitated ferric hydroxide. It is true that the salt is immediately decomposed upon complete aeration in the presence of a substantial amount of alkalinity, but in relatively low concentrations it will remain in very finely divided suspension and may in part pass through the sand of an ordinary slow or rapid sand-filter. Either the ferrous carbonate found in ground waters must decompose in intimate contact with the large surface area of previously precipitated floc on some other material, such as sand, gravel, shavings and ordinary turbidity, or it may remain for a relatively long period of time as a colloidal suspension, requiring for its flocculation an uneconomical retention period or addition of a coagulant.

The part that iron and, in some cases, manganese carbonates play in the decolorization of deep lake and reservoir waters outside of the tropics has been understood for some time. The salts are produced during summer and winter stagnation and are mixed with the entire body of water during the spring and fall overturns. They coagulate slowly in the variable currents during periods of days, weeks or months to settle with the collected organic matter into the zone of stagnation where they are regenerated into coagulants. Nature provides the long retention periods for such a process, and old reservoirs in which this cycle is well established are capable of precipitating and digesting a substantial proportion of the organic matter present in their tributary waters.

Soft Colored Waters Containing Iron and Manganese.

The development of ferric-iron coagulation of the water supplied to Providence, R. I., is admirably recorded in the Journal of this Association.* To that record must now be added a full year's operation, using ferric chloride as the coagulant. Table 1 shows the effluent characteristics of the Providence Filter Plant as averages for various designated periods during which five different coagulants have been used. Table 2 shows the average iron content and pH of the filter effluent and the average iron content of city tap samples with the increase in iron indicated for the same periods.

During the years 1928 and 1929, water was drawn almost exclusively from the intermediate-level intake in Scituate Reservoir and showed an average iron content of 0.65 p.p.m. In the early days of our efforts to solve the epidemics red water troubles, which reached their most annoying stage in the late fall and early winter of 1929, raw water containing less iron was found in the upper part of the reservoir. The upper intake was, therefore, used for the greater part of the balance of the operation period while alum was being employed as the coagulant. This reduced the raw-water iron content from 0.65 to 0.27 p.p.m. with corresponding reductions in the iron content of the filtered water.

Before it was discovered that substantial amounts of manganese existed also in the water drawn from the upper intake, the upward adjustment of the pH of the filter effluent caused the manganese to be deposited in the slime that coated the walls of conduits and pipes in the distribution system. At what pH this deposition began is not definitely known, but large amounts of manganese were present and ready to cause trouble by the first of April, 1931. The effluent pH had been raised to 9.4 by that time, when it was decided to use ammonia-chlorine treatment of the filtered water in an attempt to eliminate residual red water troubles in dead ends of the distribution system. April complaints were about one-third those received in March, but early in May complaints of black water and black stains on laundry were received. The black stain was found to be made by manganese and regular determinations of this mineral were added immediately to the routine of chemical analysis. Previous analyses had not showed the presence or absence of manganese.†

The subsequent laboratory studies in which Robert W. Sawyer‡ actively participated developed successively the feasibility of employing the four iron coagulants that have since been used.§

Reference to Table 2 shows the iron content averaging 0.03 p.p.m. in the filter effluent and city tap water, for both the last 9 months' use of anhydrous ferric sulphate and the first 10 months' use of ferric chloride as coagulants. The chemical characteristics of the average effluents are

*This Journal **45**, 334 (1931); **47**, 273 (1933); and **49**, 406 (1935).
†See discussion in This Journal **49**, 421 (1935).
‡Assistant Engineer with Malcolm Pirnie, Consulting Engineer, New York.
§Journal of the American Water Works Association **24** (1932).

TABLE 1.— PROVIDENCE FILTER PLANT.
Effluent Characteristics.

Type of Coagulant and Period of Use.	Color p.p.m.	pH	Alkalinity p.p.m.		CO_3 p.p.m.	Hardness p.p.m. $CaCO_3$	Iron Settled p.p.m. Fe	Iron Filtered p.p.m. Fe
			Methyl Orange	Phenolphthalein				
I. Alum								
1926–1927	7	7.3	4.6	0.0	1.4	15.1	0.35†	0.24*
1927–1928	7	7.7	5.6	0.0	0.6	14.9	0.37	0.32
1928–1929	6	7.9	4.7	0.0	0.3	11.2	0.31	0.23
1929–1930	3	8.7	7.7	1.3	0.0	14.3	0.17	0.08
10/1/30–8/9/31	2.7	9.2	7.5	2.2	...	17.4	0.10	0.04
II. Copperas‡ (Ferrous Sulphate)								
8/9/31–5/15/32	11.8	9.7	21.7	11.1	...	37.1	0.99	0.15
(April 1932)	(9)	(9.7)	(14.5)	(8.4)	...	(40.0)	(1.14)	(0.13)
III. Chlorinated Copperas								
5/15/32–6/23/33	9.3	9.6	14.5	7.2	...	29.0	0.50	0.06
IV. Anhydrous Ferric Sulphate								
6/23/33–9/30/33	8.0	9.3	15.9	8.2	...	29.0	0.34	0.03
1933–1934	7.0	9.7	14.1	7.2	...	25.3	0.36	0.04
1934–1935	8.0	9.6	15.6	8.4	...	25.4	0.37	0.04
10/1/35–7/26/36	6.4	9.4	17.6	8.6	...	31.4	0.33	0.03
V. Ferric Chloride								
7/26/36–6/30/37	6.3	9.5	17.5	8.7	...	31.6	0.31	0.03

*Period of 6 months. †Period of 5 months.
‡Color, pH, and alkalinity are progressively lower during first six months of treatment with copperas. April, 1932 results are given in parenthesis to show conditions at the end of the period.

TABLE 2.— PROVIDENCE FILTER PLANT.
Average Iron Contents of Effluent and City Tap Samples.

Type of Coagulant and Period of Use.	pH Filtered Water	Iron in p.p.m.		
		Filtered	City Tap	Increase
I. Alum				
1926–1927	7.3	0.24*	0.25*	+0.01*
1927–1928	7.7	0.32	0.45	+0.13
1928–1929	7.9	0.23	0.35	+0.12
1929–1930	8.7	0.08	0.18	+0.10
10/1/30–8/9/31	9.2	0.04	0.09	+0.05
II. Copperas (Ferrous Sulphate)				
8/9/31–5/15/32	9.7	0.15	0.15	0.00
April, 1932	9.7	(0.13)	(0.13)	0.00
III. Chlorinated Copperas				
5/15/32–6/23/33	9.6	0.06	0.08	+0.02
IV. Anhydrous Ferric Sulphate				
6/23/33–9/30/33	9.3	0.03	0.07	+0.04
1933–1934	9.7	0.04	0.05	+0.01
1934–1935	9.6	0.04	0.05	+0.01
10/1/35–7/26/36	9.4	0.03	0.03	0.00
V. Ferric Chloride				
7/26/36–6/30/37	9.5	0.03	0.03	0.00

*Period of 6 months.

essentially the same, except that the incrustants in the 31.6 p.p.m. of total hardness in the chloride-treated water are largely calcium chloride, instead of calcium sulphate in the 31.4 p.p.m. of total hardness resulting from Ferrisul treatment. The ability to use either ferric sulphate or ferric chloride with equally satisfactory results in this plant aids materially in placing orders for the needed coagulant at attractive prices. There is no doubt that equally satisfactory results can be obtained with chlorinated copperas, if facilities for handling and feeding it are provided. If chlorinated copperas can be delivered as a concentrated solution, it can be stored and fed in the equipment provided for ferric chloride, thus furnishing a third effective form of coagulant at this plant.

TABLE 3.— PROVIDENCE FILTER PLANT.
Average Use of Chemicals.

Coagulant.	POUNDS PER MILLION GALLONS			EFFLUENT	
	Coagulant.	Chlorine.	Lime.	pH	Hardness. p.p.m.
1. Aluminum Sulphate.....	77.5	.....	29.6	8.14	14.5
2. Copperas.....	156.7	.....	181.0	9.7	37.1
3. Chlorinated Copperas.....	109.7	15.39	134.2	9.6	29.0
4. Anhydrous Ferric Sulphate..	85.2	.....	137.5	9.56	27.3
5 Ferric Chloride.....	59.6	.....	146.9	9.5	31.6

The existing large open coagulation basins, while effective in the new treatment process, are not ideal for the present coagulation process. However, it is possible to build a new form of basin into the existing basins whenever their shortcomings justify the expense. The contribution of carbon dioxide to the water in the basins from decomposing accumulations of sludge in them requires a larger lime dose to neutralize the carbon dioxide and, therefore, increases the hardness of the effluent. The efficiency of ferric hydrate in the purification process is much less than it would be if the hydrate previously precipitated could be kept in contact with the water. Large quantities of coagulant and lime are, therefore, required, and both permanent and temporary hardness are increased. But it is evident that the point of diminishing returns is being reached in the provision of facilities for treating this water. The quality of the plant effluent is excellent, according to present standards, and further capital expenditures can be justified only by savings in operating costs sufficient to meet their capital charges. Table 3 shows the average number of pounds of chemicals used per million gallons of water treated for the five periods in which various coagulants were used.

Partial Softening of Hard Water Low in Sulphates.

The Pinellas Water Company draws water from a well field in the southwestern slope of the Ocala and Tampa limestone ground-water-high, north of Tampa Bay. This company is under contract with St. Petersburg, Fla., to furnish water with a maximum hardness of 160 p. p.m. For several years the company had met this requirement by mixing the needed amount of soft water drawn from a small lake with water drawn from the wells in limestone rock. Early in 1935, the company decided to furnish water of approximately 100 p.p.m. hardness to the city in anticipation of increased sales. Hence it authorized construction of a split-treatment

Table 4.— Pinellas Water Company, St. Petersburg, Fla.
Results of Analyses of Sources of Supply.

	Results in Parts Per Million.			
	Well No. 1.	Well No. 2.	Well No. 12.	Lake Rogers
Total Solids	213	207	219	40
Silica	13	.....	.....	0.9
Iron (Fe)	0.03	0.04	0.12	0.03
Calcium (Ca)	65	67	70	3.8
Magnesium (Mg)	4.1	3.0	3.3	1.1
Sodium (Na)	7.4	5.4	6.7	6.1
Potassium (K)	0.9			0.6
Bicarbonate (HCO_3)	218	217	229	8.0
Sulphate (SO_4)	1.1	0.7	0.9	4.2
Chloride (Cl)	10	9.0	10	11
Nitrate (NO_3)	0.05	0.05	0.05	0.05
Total Hardness as $CaCO_3$	179	180	189	14

plant which was to be as large as possible for a maximum expenditure of $110,000. The treatment plant is now operating and has been described in *Engineering News-Record.** It has a maximum capacity of 7 m.g.d. or one-third the capacity of the supply works, and includes a supply main of approximately 26 miles of 36-in. cylinder Lock Joint concrete pipe leading from the wells to connections with the distribution system in the city.

Sixty per cent. of the water from the wells is aerated through fine-spray nozzles located on the roof of the clear-water tank. The aerated water is dosed with lime and delivered tangentially into wells situated in the center of two steel tanks 50 ft. in diameter and 22 ft. high. From the wells, radial pipes distribute the dosed and mixed water over the tank bottom through orifices that serve equal areas of the tank bottom. Upward flow takes place through the calcium and magnesium carbonates that accumulate on the tank bottom. The settled, softened water is removed through orifices in collars on the tops of the central wells. Pipes convey the softened water

*September 16, 1937.

to the mixer where raw water dosed with Ferrisul is discharged through nozzles under the head used in aeration. These cause the raw water (40 per cent. of the total supply) to pick up the softened water (60 per cent. of the total supply) and to deliver the mixture at considerable velocity tangentially into a standpipe 10 ft. in diameter. The mixed water leaves the mixer tangentially and enters a central well in the coagulation tank. This tank is identical in principle to the two softening tanks. After upward-flow contact with previously precipitated iron floc, the coagulated water, containing some well-formed floc too light to settle in the upward current, is delivered to a steel-tank filter which is divided into three segments for washing. De-sludging of the various tanks is accomplished by opening hydraulic gates for one or two minutes in drain pipes connected to the bottom of the central wells. The rate of filtration is approximately 2½ g.p.m. per sq. ft., and the filter maintains this rate for about twenty-four hours.

Analyses* of water from three of the eleven wells and from the lake are shown in Table 4.

The retention in the by-passed raw water of the free carbon dioxide present in the water pumped from the wells and the release of the half-bound carbon dioxide from the bicarbonates, which is associated with a dose of Ferrisul sufficient to coagulate the mixture of by-passed and softened water, has proved, during a substantial period of operation, to furnish all of the recarbonation of the partially-softened water required to prevent subsequent deposition of normal carbonates. Dosage of Ferrisul is confined to the by-passed water which constitutes 40 per cent. of the flow. The upward-flow, calcium-carbonate precipitation and reaction tanks are adequately proportioned under all rates of operation from 3.4 to over 7 m.g.d. to furnish a softened water that is free from turbidity. The upward-flow coagulation tank causes proper flocculation of practically all of the iron present in the treated water for coagulant doses too low to give a floc that will settle in reasonable time in samples of water drawn from the mixer. Greater area in this tank, however, would materially reduce the load on the filter and can be provided when the second unit of the supply works is added within the next few years.

Table 5 gives a summary of the chemicals used and the quality of the water supplied through this plant to the city of St. Petersburg. The substantial difference in quality for July, 1937, was caused by mixing some of the soft lake water with the well water in order to reduce the consumption of lime.

Highly Colored Swamp water.

During the design of water supply works for the new kraft-paper mill of the West Virginia Pulp and Paper Company located at North Charleston, S. C., it was necessary to determine the coagulation characteristics of the Edisto River water to be sure that the supply works designed for a

*Water Supply Paper 658 *U. S. Geological Survey.*

TABLE 5.—PINELLAS WATER COMPANY, ST. PETERSBURG, FLA.
Summary of Chemicals Used and Water Quality.

Date.	Water Treated. (Million Gallons.)			Lime.		Ferrisul. (Ferric Sulphate.)	
	Aerated.	Raw.	Total.	Lb. per m.g. Aerated Water.	Lb. per m.g. Total Water.	Lb. per m.g. Raw Water.	Lb. per m.g. Total Water.
October–December 1935	.....	.....	262.84	.....	649	.....	97.3
1936	.....	.....	1 029.92	.....	685	.....	96.8
January–July 1937	443.02	295.38	738.40	1 076	646	247	99.0
1935–1937	.....	.....	2 031.16	.....	665	.....	97.6

WATER QUALITY—1937
(Results, except pH, expressed in parts per million.)

Month.	Alkalinity to Methyl Orange.			Alkalinity to Phenolphthalein.	Soap Hardness, as $CaCO_3$.		Carbon Dioxide.	pH.
	Raw.	Softened.	Filtered.	Softened.	Raw.	Filtered.	Raw.	Filtered.
January	190.5	52.5	90.9	21.1	189.9	100.5	11.2	7.94
February	191.8	51.9	91.4	25.9	185.1	100.2	12.0	8.05
March	189.0	51.9	89.1	26.3	186.4	98.4	11.0	8.01
April	188.3	50.4	91.8	21.8	185.8	99.5	9.9	7.90
May	190.5	50.6	92.5	31.3	187.2	98.5	9.0	7.89
June	190.8	49.3	92.8	21.4	188.0	100.1	9.0	7.90
July	138.7	52.6	85.6	14.9	134.8	97.8	6.9	7.78
Average	182.8	51.3	90.5	23.2	179.5	99.3	9.86	7.93

maximum rate of draft of 50 m.g.d. could be adjusted economically at a later date to furnish filtered, decolorized water if papers other than kraft paper were to be manufactured. Robert W. Sawyer demonstrated by a series of experiments with Edisto River water that it can be coagulated with anhydrous ferric sulphate to reduce the color from 170 to 10 p.p.m., or less, at a pH of about 4. A heavy, rapidly-settling floc was produced by a dose of 2 grains of Ferrisul per gallon. The methyl-orange alkalinity of the raw water was 12 p.p.m. and its pH 6.4.

TABLE 6.— BOILER FEED WATER FILTER PLANT, WEST VIRGINIA PULP AND PAPER CO., CHARLESTON, S. C.

Analyses of Water.

(Results, except pH, expressed in parts per million.)

	Raw Water	Ferrisul Treated	Settled	Aerated	Filtered	Caustic Added
September 1, 1937.						
Carbon dioxide	1	21	16	9	10	0
Soap Hardness	30	(42.)	36	36	34	34
Alkalinity (Phenolphthalein)	0	0	0	0	0	48
Alkalinity (Methyl Orange)	36	0	0	0	0	112
Chlorides	6	8	8	6	8	6
Color	180	...	15	15	10	10
pH	7.4	3.8	4.2	3.8	4.0	10.8
September 2, 1937.						
Carbon dioxide	1	...	18	14	15	...
Soap Hardness	32	...	44	42	46	...
Alkalinity (Phenolphthalein)	...	...	0	0	0	...
Alkalinity (Methyl Orange)	36	...	0	0	0	...
Chlorides	3	...	4	4	4	...
Co or	200	...	10	10	10	...
pH	7.4	...	4.0	3.8	3.9	...

	Edisto River	Shaft No. 20
Carbon dioxide	7	5
Soap Hardness	12	30
Alkalinity (Methyl Orange)	18	36
Color	200	200
pH	6.2	7.0

Later experiments, conducted by the Hall Laboratories and the Permutit Company, showed that not only did the ferric iron coagulant decolorize the water effectively, even when its color was up to 200 p.p.m., but it also caused a substantial reduction in dissolved silica. This made anhydrous ferric sulphate an ideal coagulant for preparation of part of the mill-water supply for use as feed water for high-pressure boilers. In the design of the filter plant, provision was made to deliver the water dosed with Ferrisul to two upward-flow coagulation tanks similar to those in-

stalled at St. Petersburg. The settled water was aerated on top of one of three filter tanks so constructed that clear-water storage is provided above the filters. Dosing equipment and facilities for subsequent treatment of the filtered water for delivery to the boilers were provided and their operation supervised by the Permutit Company.

It is too early to show useful results of operation of this plant, as the various devices for controlling the chemical feed have not been satisfactorily adjusted. However, when Ferrisul treatment of the raw water has been fairly constant, an excellent, low-colored filter-effluent, low in free carbon dioxide has been obtained. See Table 6. Any interruption in the coagulant feed admits raw water of relatively high pH. This, naturally, peptizes the previously precipitated floc and carries it through the aerator to cause rapid clogging of the filters and to increase the color of the effluent. Obviously, it is of utmost importance in a coagulation basin of this type to maintain a constant pH in the applied water. This requires thoroughly reliable facilities for introduction of the coagulant with potentiometer-controlled, automatic shut-down in case the coagulant feed falls below the required dose.

Colored Soft Water Containing No Manganese.

West Palm Beach, Fla. The surface water supply for West Palm Beach and Palm Beach, Fla., is collected and stored in two shallow lakes and a system of canals that intercept run-off from large swamp sloughs lying between other areas of slightly elevated sandy flats. The water is soft and varies in color between 50 and 200 p.p.m. The high colors result from heavy rains following extended dry periods. The lowest alkalinities occur at the same time. Aluminum sulphate is the coagulant. The solution from the dry-feed machines is introduced to the suction of the low-lift pumps. The dosed water is aerated through two multiple-nozzle sprays at the division section between two open, slope-paved coagulation basins. These basins are baffled by submerged end-outlet walls placed just beyond the reach of the sprays. Vertical circulation of the water in the first bays of each basin is induced by the sprays and brings floc that has already formed into contact with the freshly-dosed water. Passing around the ends of two more baffles in each basin, the settled water is conducted to open filters. Effluent flows are controlled either by spray aërators or by rate controllers and pass to a covered clear well. Hydrated lime is fed to the water as it enters the clear well. At present, the settled water is treated with ammonia and chlorine as it is delivered to the filters, and the effluent aërator is by-passed.

Prior to 1930, complaints of dirty and red water were about normal for a soft-water supply of this character, but they became substantially more than normal following periods of high-color and low alkalinity in the raw water. Addition of soda ash before or after the alum dose did not improve results. The modified log-wood test indicated substantial amounts of residual aluminum (0.58 p.p.m.) in the filtered water. Although this

aluminum did not form a visible floc in the clear well after receiving a dose of lime, there was evidence that the dirty water was caused largely by aluminum hydroxide colored with iron and organic matter in the more quiescent sections of the distribution system.

Experiments demonstrated that a well water drawn from a wave-worn bed of shells about 10 ft. thick embedded in fine sand some 90 ft. below the ground at the filter site, when mixed in proper proportion with the alum-dosed raw water, improved the speed and effectiveness of coagulation. This well water has a pH of 7.3, a bi-carbonate alkalinity of 120 p.p.m. and a color of 70 p.p.m. It contains 10 p.p.m. of free carbon dioxide. When it mixes with the alum-dosed raw water, which contains an excess of aluminum sulphate, the resulting reaction releases additional carbon dioxide to permit coagulation to go forward within the optimum range. The provision of equipment to allow measured quantities of well water to be added to the alum-treated water discharged through the low-lift pumps permits a delicate control of pH of the treated water as it is delivered to the coagulation basins. The aluminum content of the filter effluent is the measure of the desired treatment and can be maintained at not more than 0.02 p.p.m. When heavy rains suddenly add fresh color to the raw water, the alum dose must be raised substantially, and well water must be added to keep the pH of the filtered water at slightly over 6.0. The corresponding methyl-orange alkalinity lies between 6 and 7. As shown in Table 7, the average free aluminum of the effluent for the past 18 months has been 0.015 p.p.m. at pH 6.3. This is later recorded in the clear well, after lime dosage, as 0.03 p.p.m. at pH 9.5. Iron residual in the water in the clear well has averaged 0.01 p.p.m. for the past three years, and the color has averaged annually from 10.1 to 10.4 p.p.m., after having been raised to these amounts from values of 6.2 to 6.6 p.p.m. in the filter effluent by lime treatment. The iron in samples of water taken from various city taps has also averaged 0.01 p.p.m. for the past three years, indicating that there is no present tendency for the water delivered to the distribution system to dissolve iron from the pipes. The character of the water delivered through the fixtures within consumers' premises is now excellent at all times, as vouched for by the nearly complete absence of complaints.

There is no indication that the treatment at West Palm Beach can be improved by changing from alum to Ferrisul or ferric chloride as the coagulant. This is because of the cheap effectiveness of the well water in producing the necessarily delicate adjustments of alkalinity required to cause complete precipitation of the alumina. The characteristics of the treated water as delivered are set forth in Table 7 as averages of all monthly averages of the daily determinations from January 1, 1935, to June 30, 1937.

Acid Mine Waste Waters. The upper reaches of the Potomac River, containing the acid drainage from abandoned coal mines, form the source of water supply for the Piedmont, W. Va. mill of the West Virginia Pulp and Paper Co. An addition to the filter plant is being designed to increase its

TABLE 7.—WEST PALM BEACH FILTER PLANT.
Treatment and Water Quality.

	1935	1936	Jan.-June 1937
WATER QUANTITIES—m.g.			
Raw Water	1 489	1 463	869
Filtered Water	1 387	1 329	793
Total Pure Water	1 387	1 329	793
Well Water	93	140	72
Well Water—Per cent. of Raw Water	11.98	9.74	8.29
CHEMICAL TREATMENT			
Alum: 1000 lb.	697	600	324
p.p.m.	56.8	49.4	44.6
lb. per m.g.	473	411	372
Lime: 1000 lb.	148	166	99
p.p.m.	12.7	15.0	15.0
lb. per m.g.	106	125	125
WATER QUALITY—p.p.m., except pH			
Raw Water: Alkalinity	26.2	18.1	18.3
pH	7.4	7.1	7.2
Color	97.9	92.9	63.3
Hardness	33.1	27.2	28.6
Total iron (Fe)	0.03	0.06	0.07
Coagulated Water: Alkalinity	9.7	6.3	6.5
pH	6.0	5.9	6.1
Color	7.8	7.4	5.5
Carbon dioxide	10.8	10.7	10.2
After Filtration: Alkalinity	8.0	5.9	6.4
pH	6.6	6.2	6.4
Color	7.2	6.6	5.9
Hardness	42.8	....	....
Carbon dioxide	5.4	7.1	7.3
Free aluminum	0.02	0.015	0.014
Pure Water Reservoir: Alkalinity	21.9	23.6	23.9
Alkalinity Phenolphthalein	9.8	11.9	12.0
pH	9.2	9.5	9.6
Color	10.4	10.1	7.1
Hardness	55.4	55.6	56.0
Total iron(Fe)	0.01	0.01	0.01
Free aluminum	0.04	0.036	0.03
Well Water: Alkalinity	120.7	117.2	120.5
pH	7 3	7.3	7.4
Color	67.7	73	65
Carbon dioxide	10.2	10.6	10.3

nominal capacity from 12 to 18 m.g.d. and a search is being made for the most efficient use of existing structures, in order to conserve the limited area available for expansion. The existing coagulation basin can be converted into an upward-flow contact basin, with a maximum rate of rise of the treated water through the previously precipitated floc of approximately 1 in. per min. Experiments are being conducted by J. G. Patrick, Chemist of the Piedmont plant, in a small experimental plant to demonstrate the effectiveness of the proposed treatment for raw water of varying characteristics. The river water varies from a pH of less than 4 to one of more than

7, depending upon the degree of dilution of the mine wastes by the relatively soft water running off the drainage area. The mine drainage contributes ferrous and manganous sulphates. These require coagulation at high pH, if both of these minerals are to be eliminated from the filtered water. The present operation is to adjust the alkalinity of the water to a pH of 7 by the use of caustic soda and to coagulate the water with alum when the river water is turbid. This produces a filtered water containing a substantial amount of iron and practically all of the manganese in solution, but water of this quality has proved to be reasonably satisfactory in recent years for use in the mill. The proposed treatment substitutes anhydrous ferric sulphate for alum. It is followed by lime treatment in a mixer to adjust the pH of the water to 9 and by upward-flow sedimentation in the existing coagulation basins.

Pre-Treatment of Small Impounded Soft-Water Supply. The wooden tub rapid sand-filter plant treating the water obtained from a chain of reservoirs on the Pocantico Hills Estate of John D. Rockefeller, Jr., has for years produced a corrosive effluent. The encrusted condition of the pipes in the filter underdrains and of the pure-water pipes leading from the filters to the distribution system gave clear evidence of the activity of this treated water. At the time the filters were overhauled, a cylindrical, upward-flow coagulation tank with a dome roof was designed and built under an earth cover to provide a relatively non-corrosive, coagulated water for application to the filters. The supply from the reservoirs is first treated with approximately one grain per gallon of ferric chloride and mixed with lime in the center well to create a pH of approximately 9. Excellent coagulation results. At an upward-flow rate of about 1½ in. per min. a low-colored water, containing a very small amount of floc, is delivered to the filters.

It seems clear, from the thoroughly satisfactory results obtained with alum coagulation of soft, highly-colored water at West Palm Beach, that substantial improvement in treatment of other soft, colored waters might be obtained if alkalinity required to adjust the reaction could be added in a form to maintain the needed low pH of the treated water. Possibly, carbonated solutions of soda ash or lime may prove to be effective in the absence of well waters containing bicarbonate alkalinity with an excess of free carbon dioxide. Carbonation of submerged beds of crushed limestone or carbonation of mixtures of water and powdered limestone may also prove to be cheap and effective. This opens an interesting field for further experiments.

Conclusion.

Progress in water purification during the first quarter of the twentieth century was so rapid in its demonstrated protection of the public health that, to the casual observer, little remained for future generations to accomplish. However, in the late twenties, when water-borne typhoid fever and epidemic summer complaint had ceased to visit the majority of our large communities, the average water consumer was growing tired of complaining about the physical quality of water that he occasionally drew from the plumbing fixtures in his house. Either pipes were filling up so rapidly that service pressure was inadequate, or the water was dirty, rusty or had a disagreeable taste and odor. He could not be satisfied by assurance from the water department that the water was excellent when it left the reservoir or the filter plant. He did not like to be told that the trouble was in the plumbing system hidden in the walls and floors of his house. Fire chiefs were beginning to report less water available at hydrants than formerly, and superintendents of distribution systems were exhibiting to managers of water works sections of pipe, cut from mains, which were incrusted or tuberculated to a degree that explained the reported losses in distribution capacity. To improve these conditions, became the problem of investigators and operators. This work is of substantial magnitude, and while it is not so spectacular as the health improvement accomplished in the first quarter of the century, it is making for progress during this second quarter and will continue to do so for years to come. Some of the efforts made by the author and some of the results accomplished in recent years and months have been briefly outlined in the hope that they may prove of interest to other designers of water works and to operators of water treatment plants.

Discussion.

L. W. Cutler.* The contact type of filter is limited in its application to those waters in which the objectionable characteristics consist of iron and free carbon dioxide. In other words, those waters in which the carbonate hardness and organic color do not exist in objectionable quantities. In Florida such waters are encountered in many localities. That at Stuart is representative of those waters which might be classed as medium hard, while at Pensacola we have an extremely soft water, much like that mentioned by Mr. Pirnie in his description of the Long Beach, Long Island plant. We have made six installations here in Florida; all are in continuous operation.

It is our experience that where the water falls in this category, the contact-type filter possesses outstanding advantages over any other type. A successful application depends mainly upon the selection of the proper degree of preliminary aëration determined, as Mr. Pirnie points out by the comparative carbonate hardness. Since this factor does not change ma-

*Refrigerating Engineer, Florida Power and Light Co., Miami, Florida.

terially from time to time, no adjustments, either mechanical or chemical, are required. In short, the operation is limited to filter washing which proves even less of a problem than he mentions. The down-washing is limited to approximately once a week and the pressure up-wash to once a month. Incidentally, this wash water with its high iron content is ideal for irrigating a field of rose bushes or other flowers where vivid color of blossom is desired.

The higher the iron content in the raw water, the more complete and gratifying the results of iron removal. Iron contents up to 15 to 20 p.p.m. are reduced continuously to 0.05 p.p.m., and samples frequently run as low as 0.02 p.p.m.

It is recommended that the contact of iron with the water be avoided in the construction of the equipment from the point of preliminary aëration through that of final aëration. Thus the original free carbon dioxide or that freed by the formation of ferric hydroxide is prevented from re-dissolving any additional iron. Thus, in one installation the iron content on top of the filter bed of 0.02 p.p.m. was increased to 0.06 p.p.m. on its passage to the final aërator through a short run of iron pipe. In the last installation at Pensacola, concrete was the only material used, including the lip of the final aërator, and no boost in the iron content has been experienced. Obviously, the final aëration should be as complete as possible, especially with a water running low in carbonate alkalinity.

PROCEEDINGS.

FIFTY-SIXTH ANNUAL CONVENTION.

POLAND SPRING, MAINE.

September 21 to 24, 1937.

The following is a synopsis of such parts of the proceedings of the Fifty-sixth Annual Convention as appear to be of value for the record.

The Fifty-Sixth Annual Convention of the NEW ENGLAND WATER WORKS ASSOCIATION was held at Poland Spring Spa, Poland Spring, Maine, September 21 to 24, 1937.

TUESDAY, SEPTEMBER 21.

Morning Session.

The Convention was called to order by President Harry U. Fuller at 11 A.M.

ADMINISTRATIVE REPORTS.

The Annual Reports of the Secretary, Treasurer, Editor and Finance Committee were presented (see p. 466), accepted and placed on file.

CLOSING OF POLLS AND APPOINTMENT OF TELLERS.

THE PRESIDENT declared the polls closed and appointed three tellers: Arthur C. King, Donald C. Calderwood and Henry F. Hughes.

The Secretary announced the election of the following:

Members: Leigh Irving Holdredge, Oneonta, N. Y.; Charles Warren Harris, Hinsdale, N. H.; John True Bergeson, Charleston, S. C.; Arthur Boniface, Scarsdale, N. Y.; J. Arthur Carr, Ridgewood, N. J.; Wilfred J. Michel, Somersworth, N. H.; Harry A. Faber, New York City; James P. Joyce, Holyoke, Mass.; John A. Andrew, North Chelmsford, Mass.; Francis J. McCarty, Somerset, Mass.; Harry J. Krum, Allentown, Pa.

Associates: Activated Alum Corp., New York City; The Barrett Company, New York City; Carson-Cadillac Corp., Birmingham, Ala.; The Farnan Brass Works Co., Cleveland, Ohio; Proportioneers, Inc., Providence, R. I.; Fields Point Mfg. Co., Providence, R. I. (reinstated).

Luncheon Session.

The President introduced Mr. Harry L. Jordan, Secretary of the American Water Works Association.

An address of welcome was given by David E. Moulton, Attorney, Portland Water District, Portland, Me., and President of the Maine Water Utilities Association.

Address of Welcome.

by David E. Moulton.*

Ladies and gentlemen; members of the New England Water Works Association: As your President has said, I am at present the President of the Maine Water Utilities Association. As such, it was decided that I should welcome This Association to the State of Maine. I could not understand just why I should do the job rather than the Governor, as is usual, except that I was told that to ask the Governor was old fashioned, especially when he was a Republican Governor.

Mr. Fuller was the most insistent of all that I should do the honors. I was unsuspecting, I could not understand just why he was so interested in my behalf. I have since found out. It has been my pleasure for something over twenty years to meet in daily consultation with Mr. Fuller, or perhaps I might more correctly say in daily dissension with him. During all of that time I have done my best, in a humble way, to have him appreciate the relative importance of the legal and the engineering professions so far as water works management is concerned, and I think I may justly claim that to be one of the reasons why he is so modest and retiring as compared with some of the other engineers with whom you are acquainted. But the principal reason that I now believe was behind his insistence was that he has put me on the spot where I have to say something nice to the engineers. After abusing them for about twenty years, you may appreciate the position in which I find myself; and so for the past few weeks I have been trying my best to think of something nice that I could say about an engineer. To my surprise, almost every day I have thought of something, and to my humiliation it has come back home to roost.

At first I thought I could praise them for their assistance to you practical water works men in running your water works system; but I know enough about the game to know it is more apt to be the other way around: that most of the information they have is what they get from you practical water works men. They, however, have the ability and the forethought to put those ideas that you put into their minds on record so that at some future time, if their acquaintance is broad enough, they can serve you as a consulting engineer and charge you for what some other good water works man has told them. So I can't praise them for the assistance they give to you practical men. The humiliating part comes in that, as a public utility lawyer, I have to admit that the only place I can put them where they are in step is with the lawyers. I won't tell what kind of a step that would be if they were properly placed; it might even be a lock step.

I think a consulting engineer a long ways from home, on the witness stand with a slide rule in his hand, has the most imagination of anything the Lord ever conceived. The old mathematical bogie who said the whole could not exceed the sum of its component parts, never heard an expert

*Attorney, Portland Water District, Portland, Maine, and President of the Maine Water Utilities Association.

engineer theorizing on reproduction. I certainly admire a man who can build up in his mind and reconstruct in a valuation case actual water works out of the air. He will start in with the ledge trenches and will tell the court that the cost of removing them has got to be included, although they were removed fifty years ago and they are only theoretically reproduced. The value in those ledge trenches is something remarkable! Then after he has convinced the court that it must include the cost of those ledge trenches, even if no ledge existed at the present time, he will with equal fervor convince the court that you have to pay for cutting the new pavement because it *is* there, even though it was *not* there when the trench was originally constructed. And that is "only the beginnin," as Captain Henry says,— "only the beginnin."

The insurance company that talks about the Rock of Gibraltar has nothing on an expert engineer telling about the virtues of cast-iron pipe. I have heard an engineer under oath say that it has a life of five hundred years, and I have begun to admire cast-iron pipe for qualities that I never appreciated before. But it is when the engineer gets to the higher realms of imagination, when he gets to water works valuation, that we ordinary fellows realize we are beyond our depth; especially when he gets to intangibles, and that intangible of all intangibles, going value — going, going, going. It goes so high that it usually covers the fees of both the engineers and the lawyers.

So I am obliged to most humbly extend my apologies to the engineers and ask pardon from my fellow workers in the engineering profession for all that I have said in the past twenty years to their detriment; and welcome you to the State of Maine, not as expert engineers but, let me say — well, I will call you recording angels,— recording the doings of the humbler men in the water works profession and placing them where they may be available, whereas otherwise those records of achievement might have been lost.

Also I would like to welcome the real water works men.

I know there is one thing that you will enjoy here above everything else. This is the only place that I know of where the water works men of New England, or of America, or of the whole world can have a drink of water without paying tribute to the manufacturers of purifying equipment. You can take a drink of Poland Spring water and know that you have not contributed anything for mechanical or chemical treatment of any kind. Another thing about Poland Spring water. It does not serve simply a metropolitan district; it covers the entire world. There is hardly a first-class hotel in the civilized world where you cannot get a drink of Poland Water, which originates a few hundred feet from here at the top of the hill. Here is a real water system for you, gentlemen, untreated, unblemished, right from Nature's reservoir. Before you leave, you must go down to the spring house and see what Nature has done for Maine.

By the way, speaking of Maine, just think of the kindness and consideration that we have shown you people after you have seceded from the

United States, to give you free entry into this territory which represents the major portion of what our great grandfathers fought to achieve: Liberty.

We cannot, perhaps, treat you as well as we did the other organization that came into Maine a few months ago and got into difficulty. They accused us of not knowing our A B C's. They said we did not know what CIO stood for. It had to go to the court, and after the court put them where we could best entertain them — in the Androscoggin County Jail — and fed them for nothing, they did not appreciate it, and said we were a hundred years behind in our labor laws. Well, we may be one hundred years behind, but you can come here to Maine, the playground of the nation, and if you do want to work it is not against the law to work in Maine.

Moreover you may go into your own offices and your own factories if you please, and if there is anybody who attempts to prevent you and we turn out the militia, it will not be to keep you from running your plant but to see that you can do as you please with your own. Here, in what is left of the United States, we also have the United States mails delivered to us. We are a long way from the center of population, but we do have some of the comforts of civilization.

And so, ladies and gentlemen, I hope you will enjoy your stay here in what is left of that great country that we fought for when we declared our independence over a hundred years ago, and which you fellows have been signing away ever since. But here law and order prevail, Nature smiles upon you, and if you don't have a good time and don't accomplish something it will be your own fault.

Award of Dexter Brackett Memorial Medal.

E. Sherman Chase. Mr. President, Members and Guests of the New England Water Works Association: There are two honors within the power of This Association to confer, one being honorary membership in the Association, and the other the Dexter Brackett Memorial Medal for the most meritorious paper published during the previous year.

This year, as I believe in most years, the committee on award had a difficult time in selecting the most meritorious paper. Every year in the Journal there are published papers of outstanding merit, but it was the unanimous opinion of the committee this year that the paper by Mr. George C. Bunker, upon "Water Supply Problems in the Tropics of Spanish America," published in the March, 1936, issue of the Journal, was the paper most deserving of the award. As a result, it is with great pleasure that I announce the award of this medal to Mr. Bunker, who is unable to be here.

Mr. Bunker was born in New Hampshire, in the town of Bethlehem, some fifty years ago. His second water supply job was connected with the Portland Water District. For many years Mr. Bunker has practiced in the

Canal Zone, and he is probably one of the outstanding experts in the world upon tropical water supplies.

Mr. Bunker sent me a brief note of appreciation, which, with your permission, I will read:

Mr. President, Chairman of the Committee on Award of Dexter Brackett Memorial Medal, Members of the Association:

I regret exceedingly that I am unable to attend the Fifty-sixth Annual Convention of the Association in order to accept the Memorial Medal. Thank you personally for it, and be assured of the great satisfaction and pleasure which the bestowal of this honor is affording me.

With my best wishes for a very successful and very interesting convention, as the program indicates it will be, and with kindest regards, I am,

Very truly yours,
(Signed) GEORGE C. BUNKER.

Afternoon Session.

A paper "New Uniform Accounting System for Water Utilities in Maine," was read by Allan F. McAlary, Treasurer, Camden and Rockland Water Company, Rockland, Maine.

Francis H. Kingsbury, Fred J. Reny, Percy A. Shaw, David E. Moulton, Frank J. Gifford, H. L. Jordan, William W. Brush, Theodore L. Bristol, and Horace J. Cook took part in the discussion.

A paper "New River Crossing at Augusta, Maine," was read by Sidney S. Anthony, Engineer and Superintendent, Water District, Augusta, Maine.

Harold L. Brigham, Warren J. Scott, George A. Sampson, and Leavitt R. Smith took part in the discussion.

A paper "Meeting the Demand for Recreation Facilities Near Public Water Supplies," was read by David E. Moulton, Attorney, Water District, Portland, Maine.

Warren J. Scott, Harold L. Brigham, Percy A. Shaw, Francis H. Kingsbury, Adolph Mueller, and Fred J. Reny participated in the discussion.

A paper "Economics of Water Purification," prepared by Arthur L. Shaw and E. Sherman Chase, of Metcalf & Eddy, Consulting Engineers, Boston, was read by Mr. Chase.

Percy A. Shaw, William B. Duffy, Donald C. Calderwood, Gordon M. Fair, and Francis H. Kingsbury took part in the discussion.

WEDNESDAY, SEPTEMBER 22.

Morning Session.

President Harry U. Fuller in the chair.

Progress reports of committees were presented as follows:

Arthur C. King: Legislative Committee.
Stephen H. Taylor: Committee on Plumbing Fixtures.
W. R. Conard: Committee on Standardization of Pipe Flanges and Fittings.
W. R. Conard: Committee on Specification for Cast Iron Pipe and Special Castings.
George A. Sampson: Committee on Grounding of Electric Currents on Water Pipe.
Robert Spurr Weston: Committee on Education.
Harold L. Brigham: Committee on Membership.

These progress reports were accepted and placed on file.

Dr. Frank N. Speller, Director of Metallurgy and Research, National Tube Company, Pittsburgh, Pa., led a Symposium on Corrosion. Dr. Speller opened the Symposium by a talk on "Principles of Corrosion and its Prevention."

Papers were read by the following:

"The Corrosion Problem in Cambridge, Mass.," by Melville C. Whipple, Assistant Professor of Sanitary Chemistry, Harvard Graduate School of Engineering, Cambridge, Mass.

"Influence of Dissolved Oxygen in Accelerating Corrosive Action of Water," prepared by F. Wellington Gilcreas, Associate Sanitary Chemist, Division of Laboratories and Research, State Department of Health, Albany, N. Y., and read by Robert Spurr Weston.

"The Neutralization of Corrosive Action," by Robert Spurr Weston, Weston and Sampson, Consulting Engineers, Boston, Mass.

Messrs. H. L. Clark, D. William Harford, Malcolm Pirnie, David A. Heffernan, E. Sherman Chase, Linn H. Enslow, and Stuart E. Coburn took part in the discussion.

A paper "Pipe Coating Practice in England," prepared by J. Mitchell, Stewarts and Lloyds, Ltd., London, England, was read by Gordon M. Fair.

A paper "Development and Use of Spun Bituminous Coatings for Water Pipe," was read by George E. Boyd, District Manager, Wailes Dove-Hermiston Corporation, New York, N. Y.

These two papers were discussed by William W. Brush, Henry T. Gidley, Stephen H. Taylor, Roger W. Esty, Percy A. Shaw, David A. Heffernan, Harold L. Brigham, and Theodore Cate.

THURSDAY, SEPTEMBER 23.

Morning Session.

Karl R. Kennison presiding.

A Symposium on Gravel Packed Wells was led by Paul F. Howard, who read a paper "Experiences with Low-Velocity Gravel-Packed Wells."

A paper "Gravel-Packed Wells at Needham, Mass.," was read by Bayard F. Snow, President, X. Henry Goodnough, Inc., Engineers, Boston.

Roger G. Oakman, Superintendent of Water Works, Needham, spoke on the operation of the Needham system.

A paper "Additional Ground Water Supply for Woburn, Mass.," was read by John P. Wentworth, Metcalf & Eddy, Boston, Mass.

These three papers were discussed by Charles W. Sherman, R. W. Horne, and Percy R. Sanders.

A paper "Spillway Design for the Bills Brook Dam at Barkhamsted, Conn.," was read by William Dorenbaum, Designing Engineer, Water Bureau, Metropolitan District of Hartford County, Connecticut.

A paper "Some Filter Operation Experiences with Iron Coagulants," was read by Malcolm Pirnie, Consulting Engineer, New York, N. Y.

Attmore E. Griffin, Linn H. Enslow, and J. J. McCarthy took part in the discussion.

Afternoon Session.

SUPERINTENDENTS' SESSION.

Percy A. Shaw, presiding.

A paper "Qualification of Water Treatment Plant Operators," was read by Warren J. Scott, Director, Bureau of Sanitary Engineering, State Department of Health, Hartford, Conn. Percy A. Shaw and Francis H. Kingsbury took part in the discussion.

A paper "Measurement of Sand Expansion," prepared by H. J. Krum, City Chemist, Allentown, Pa., and Everett M. Jones, Simplex Valve & Meter Company, Philadelphia, was read by Mr. Krum. Everett M. Battey and Everett M. Jones took part in the discussion.

A paper "Fire Hydrant Connections and the Control of Dual Mains," was read by Arthur F. Ballou, Fire Prevention Engineer, National Board of Fire Underwriters, New York, N. Y. Stephen H. Taylor, David A. Heffernan, W. C. Hawley, Donald C. Calderwood, Charles W. Sherman, Harold L. Brigham, Daniel M. Sullivan, Arthur C. King, Howard M. King, Leland G. Carlton, and William W. Brush took part in the discussion.

A paper "New Developments in Fluid Meters which May Affect Water Meter Designs," was read by Walter Parker, Department Manager, Pittsburgh Equitable Meter Company, Pittsburgh, Pa J. Herman Smith discussed the paper.

Several reels of moving pictures illustrating "Modern Practice in the

Manufacture and Laying of High Pressure Reinforced Concrete Pipe" were shown and described by Colonel F. F. Longley, Vice President, Lock Joint Pipe Company, Ampere, N. J. Leavitt R. Smith, Stephen H. Taylor, William W. Brush, Linn H. Enslow, and Francis H. Kingsbury took part in the discussion.

FRIDAY, SEPTEMBER 24.

Morning Session.

President Harry U. Fuller in the chair.

REPORT OF TELLERS OF ELECTION.

The Tellers submitted the following report:

Number of ballots cast	223
Ballots counted	223
For President, WARREN J. SCOTT	222
For Vice President, PERCY A. SHAW	220
For Directors, HAROLD J. BRIGHAM	220
For Treasurer, LELAND G. CARLTON	221

(Signed) D. C. CALDERWOOD,
HENRY F. HUGHES,
ARTHUR C. KING, *Chairman.*

CHARLES W. SHERMAN offered the following resolutions:

RESOLVED, that the thanks of the New England Water Works Association are hereby extended to the Maine Water Utilities Association, and especially to the committee of ladies appointed by that association, for the many things they have done to make this convention so successful and enjoyable.

RESOLVED, that the thanks of the New England Water Works Association are hereby extended to the Water Works Manufacturers' Association for their cordial assistance in arranging for and conducting this convention.

[These resolutions were duly seconded and unanimously carried.]

PRESIDENTIAL ADDRESS.

By Harry U. Fuller, Retiring President.

The reports of the Secretary, the Treasurer, and the Editor show that This Association is in good condition. The association is fortunate in having these continuing officers, and I hope we may continue to enjoy the benefits of their experience and good work.

The various committees have done good work and maintained the high standard of the association's activities.

I want to say to you that I have enjoyed the experience of serving as president. I have found without exception that when I asked a member to do a task, he has accepted heartily and has always done well. This spirit

of friendly helpfulness from all the members I greatly appreciate. I know you will show the same fine spirit to the new president, Warren J. Scott.

One matter that I would like to discuss with you is the activities of This Association.

This Association stands in a rather unique position, with its membership international, its name sectional, and its winter meetings serving as a state meeting for Massachusetts with some inflow from the surrounding states.

We are not giving the same quality of service to the other New England States that we are giving to Massachusetts. This is due to the location of the meeting place. We have recently made a step in the right direction with the inauguration of northern and southern New England meetings once yearly. I think steps should be taken to provide more meetings in the other New England States. The average water works operator cannot travel very far to attend a meeting, but my experience leads me to think that meetings held within about a hundred miles of a water works operator will draw him.

Perhaps the first step toward giving the Association's service to the operators of water works in the various New England states would be the formation of committees in each state. Such committees could survey the conditions in their states and suggest a method of procedure. Chapters or branches of This Association might be formed, or independent state associations.

Our very efficient secretarial department could render valuable assistance in the formation of an independent association, or a branch chapter, and in the functioning of the body after its formation. This, I think, would be a reasonable service to render to the water works operators who are not now receiving the benefits that I think they should receive.

The winter meetings in Boston have increased in the variety of their activities as the years went by. The afternoon meetings with papers and committee reports on water works subjects continue to hold the interest of the members, and their publication maintains the high standard of the JOURNAL.

The superintendents' round table, the lectures, and the more recent chemists' round table in the mornings, continue to grow in popularity.

Some parts of these activities should be carried to the different parts of New England, near enough and often enough to the smaller water utilities to give them more of the benefits of the Association.

We must make some improvements and changes each year, and the foregoing suggestions are my ideas of the next steps.

The second thought I wish to present for your consideration is the importance to the water users of an independent financial set-up.

When a community goes into the business of supplying itself with water, it is only fair to the citizens who compose the community that they know how their business is succeeding. They cannot know the truth unless the records are kept in such a way as to show the investment in the plant,

the real annual income and operating cost, and the profit or loss. Many communities do not realize the importance of knowing the truth, and sometimes it better serves the purposes of local politicians that the truth is not known.

It is not only important that the finances of the water works be kept separate from other activities of the community, but it is important to the citizens of the community that the different classes of customers of the water works pay what it costs to serve them. Even if this cannot be done at this time, it is well to know the truth so that when changes are possible they may be made in the right direction.

Most of the states have some form of a public utility commission. It seems probable that if all water utilities in a state, both publicly and privately owned, were placed under the control of such a body, the final result would be beneficial to the citizens who use the water service.

Public Utility Commissions in the coming years are going to require that water utility records be so kept that they reflect its operations. These commissions are created to prevent discrimination, and the tendency as time passes will be to reduce the amount of discrimination. This will be to the advantage of the citizen as well as the water works operator.

During the coming year this subject of independent water works records might well be discussed by the members of This Association, as well as the matter of commission control of publicly owned water utilities.

CHARLES W. SHERMAN. I know it is not customary to discuss the presidential address, but there was one suggestion in your address which seems to me might have been extended a little more and perhaps is worth calling attention to further for the benefit of the Association.

I refer particularly to the matter of the forenoon round table sessions at our monthly meetings, the superintendents' sessions and the chemists' sessions. I know it is impossible to report them as we do our afternoon meetings, and I know also that we would not get the kind of discussion there that we want if the speakers knew that reporting was being done; but it does seem as though there ought to be some way by which the chairman of the meeting, or some other competent person, would be able to prepare some kind of a brief summary of those round table meetings for publication in the JOURNAL, touching the high points and leaving out extraneous or redundant matters. I believe there is room for real advance in getting in the JOURNAL statements of experience that may be of even more importance than our formal papers.

THE PRESIDENT. I am glad that Mr. Sherman has made those suggestions. I have seen the idea worked out in another water works association. The best scheme evolved was to delegate one member to make notes and approach the speakers who had made a contribution to write down their remarks and send them in for publication.

The President then introduced President-Elect Warren J. Scott.

MR. SCOTT. I am very appreciative of the honor, and knowing the real hard work that Harry Fuller and Roger Esty and all of their predecessors

have put on the job, I appreciate the fact that I have a real job ahead of me, which I will try to fulfil. I thank you. [Applause.]

Superintendents' Round Table.

Harold L. Brigham, Superintendent, Marlborough Water and Sewage Commission, Marlborough, Mass., presiding.

A paper "Rate Structures," was read by Theodore L. Bristol, President, Ansonia Water Company, Ansonia, Conn. David E. Moulton, Roger W. Esty, Donald C. Calderwood, Harry U. Fuller, Charles W. Sherman, W. C. Hawley, Henry T. Gidley, Ernest A. Merrithew, and Frank J. Gifford took part in the discussion.

A paper "Collection of Water Bills," was read by Charles E. Easter, Superintendent, Water Works, Claremont, N. H. Donald C. Calderwood, Henry T. Gidley, Warren J. Scott, Percy R. Sanders, Theodore Case, and William W. Brush participated in the discussion.

A paper "Should Fire Hydrants Be Painted to Indicate Capacity," was read by Joseph W. Randlette, Superintendent and Treasurer, Richmond Water Works, Richmond, Me., and President of New England Fire Chiefs Association. Donald C. Calderwood, Ernest A. Merrithew, William W. Brush, and Harold L. Brigham took part in the discussion.

A paper "Should Relocation Due to State Highway Projects Be Paid for by the State," was read by Ernest A. Merrithew, Superintendent, Public Works Department, Saugus, Mass. This paper was discussed by William B. Duffy, Frank J. Gifford, Donald C. Calderwood, Roger G. Oakman, Roger W. Esty, and W. C. Hawley.

A paper "Dual Mains," was read by Daniel M. Sullivan, Deputy Commissioner of Public Works, Boston, Mass. Roger W. Esty, Joseph W. Randlette, David A. Heffernan, Leland G. Carlton, and William W. Brush took part in the discussion.

A paper "Water Works Funds for Water Works Purposes," was read by Leland G. Carlton, Registrar, Water Works, Springfield, Mass. Roger W. Esty discussed the paper.

Chemists' Round Table.

Stuart E. Coburn, Chief Chemist, Metcalf & Eddy, Boston, Mass., presiding.

Papers were read as follows:

"What Is a Safe and Satisfactory Drinking Water," by Stuart E. Coburn;

"Sanitary Survey of Sources," by Charles L. Pool, Sanitary Engineer and Chemist, State Department of Health, Providence, R. I.;

"Chemical Analyses," by Gail P. Edwards, Laboratory Coördinator, Massachusetts Department of Health, Boston, Mass.;

"Bacterial Analyses," by E. W. Campbell, Director, Division of

Sanitary Engineering, Department of Health and Welfare, Augusta, Me.; and

"Microscopic Analyses," by Marshall S. Wellington, Sanitary Engineer and Superintendent of Chlorination, New Haven Water Company, New Haven, Conn.

These papers were discussed by Stuart E. Coburn, Marshall S. Wellington, Arthur G. Booth, Percy A. Shaw, Gail P. Edwards, Francis H. Kingsbury, Arthur V. Harrington, and Charles L. Poole.

Mr. Fuller then turned over the meeting to President Scott.

PRESIDENT SCOTT. I think most of you feel, as I do, that we have had a most successful convention. I think that the thanks which are due to Mr. Fuller, Mr. Moulton, and all those others who have participated in making the meeting so successful, have already been incorporated n the resolutions that were offered this morning, so that if there is no further business we shall stand adjourned until the November Meeting.

[Adjourned.]

Annual Report of the Secretary.

Mr. President and Gentlemen of the New England Water Works Association:— The Secretary submits herewith the following report of the changes in membership during the past fiscal year, and the general condition of the Association.

The present membership is 783, constituted as follows: 12 Honorary Members, 650 Members, 99 Associate Members, and 22 Corporate Members. The detailed changes are as follows:

MEMBERSHIP.

September 1, 1936.	Honorary Members	13			
	Withdrawals:				
	Died	2	11		
	Elected:				
	September, 1936		1		12
September 1, 1936.	Members Total		634		
	Withdrawals:				
	Resigned	6			
	Died	13			
	Dropped by Executive Committee	2			
	Elected to Honorary Membership	1	22	612	
	Elected:				
	September, 1936	8			
	November, 1936	16			
	December, 1936	2			
	January, 1937	1			
	February, 1937	3			
	March, 1937	3			
	April, 1937	2			
	May, 1937	1		36	
	Reinstated:				
	September, 1936	1			
	November, 1936	1		2	650
September 1, 1936.	Juniors, Total		0		
September 1, 1937.	Juniors, Total		0		0
September 1, 1936.	Associates, Total		94		
	Withdrawals:				
	Resigned	4		90	
	Elected:				
	September, 1936	4			
	February, 1937	1			
				5	
	Reinstated:				
	September, 1936	3			
	April, 1937	1		4	99

September 1, 1936.	Corporates, Total	20	
	Elected:		
	November, 1936	1	
	March, 1937	1	
		—	22
September 1, 1937.	Total Membership		783
September 1, 1936.	Total Membership		761
	Net Gain		22

ELECTIONS.

Honorary Members.

September 22, 1936. Thaddeus Merriman. (1)

Members.

September 22, 1936. Christopher F. Bingham, Frank Allen Chase, Eugene A. Drumm, Thomas Aloysius LaCava, W. W. Morehouse, Marshall Barker Palmer (reinstated), Ralph L. Pollard, Leslie Sherman and George Allen Stetson. (9)

November 19, 1936. Everett M. Battey, Maurice Burwick, Harold L. Carter, George J. Cote, Wayne F. Damon, Michael J. Hannigan, Henry C. Jones, John D. Mackay, Ernest A. Merrithew, Morton R. Milne, Edward W. Moore, John B. Moore, Fred B. Nelson (reinstated), Lyndall K. Parker, William J. Perry, 2nd, Eugene M. Repucci and Ernest E. Tankard. (17)

December 17, 1936. John M. Magee and Ralph A. Marble. (2)

January 21, 1937. Carl A. Clark. (1)

February 18, 1937. Charles R. Cox, John W. Hughes and Joseph E. Tracy. (3)

March 18, 1937. George G. Bogren, Hugh J. McLaughlin and Kenneth W. Robie. (3)

April 29, 1937. J. R. Dangler and William Edward Hogan. (2)

May 20, 1937. Carter H. Lamb. (1)

Associates.

September 22, 1936. Birch Manufacturing Company (reinstated), Darco Corporation, W. & L. E. Gurley (reinstated), Homelite Corporation, McWane Cast Iron Pipe Company (reinstated), Reilly Tar & Chemical Corporation and L. A. Salomon & Bros. (7)

February 18, 1937. J. H. Tredennick, Inc. (1)

April 29, 1937. National Tube Company (reinstated). (1)

Corporates.

November 19, 1936. Milford Water Company. (1)

March 18, 1937. Water and Sewer Commissioners, Westboro, Mass. (1)

RESIGNATIONS AND DEATHS.

Honorary Members.

Died: Harrison P. Eddy and Frank A. McInnes. (2)

Members.

Resigned: Homer E. Bridge, Irving B. Crosby, John F. Laboon, Earl E. Mooney, C. L. Scofield and Everett E. Turkington. (6)

Died: H. N. Blunt, Walter I. Brown, Walter J. Connor, Edward D. Eldredge, John H. Gregory, Nicholas S. Hill, Jr., Lawrence C. Hough, Harrie M. Howe, James W. Killam, William P. Mason, Charles W. Mowry, John H. Read and Harley E. Royce. (13)

Dropped by Executive Committee: George Eric Barnes and Jesse P. Carpenter. (2)

Associates.

Resigned: Columbian Iron Works, W. C. Lipe, Inc., Reading Iron Company, Anthony Ross & Son. (4)

RECEIPTS FOR THE FISCAL YEAR, SEPTEMBER 1, 1936 TO SEPTEMBER 1, 1937.

Entrance Fees			$ 256.00
Annual Dues:			
Members	$3 112.32		
Corporates	180.00		
Associates	1 885.00	$5 177.32	
Fractional Dues:			
Members	$ 72.00		
Corporates	10.00		
Associates	15.00	97.00	
Past Dues:			
Members	$ 108.00		
Associates	40.00	148.00	
1937–1938 Dues:			
Members	$ 56.00	56.00	
Total Dues			5 478.32
Dividends and Interest			449.48
Advertisements			3 082.20
Subscriptions			484.00
JOURNALS			79.75
Reprints			901.28
Sundries			23.75
Total Receipts			$10 754.78
There is due the Association:			
Entrance Fees		$ 3.00	
Dues		750.00	
Advertisements		401.00	
JOURNALS		6.25	
Reprints		56.64	
Halftone		6.00	1 242.89
Total			$11 997.67

Respectfully submitted,
(Signed) FRANK J. GIFFORD, *Secretary.*

Annual Report of the Treasurer.

September 1, 1936 to August 31, 1937.

The President and Members of the New England Water Works Association:—I herewith submit as my report for the year ending August 31, 1937, the following statement from Messrs. Scovell, Wellington & Co., accountants.

Respectfully submitted,
(Signed) Leland G. Carlton, *Treasurer.*

Springfield, Mass., September 15, 1937.

Leland G. Carlton, *Treasurer,*
New England Water Works Association,
Springfield, Massachusetts.

Dear Sir: In accordance with your request, we have made an examination of the accounts and financial records of the New England Water Works Association for the year ended August 31, 1937.

We submit herewith the following attached statements:

Exhibit A. Statement of Assets and Funds as at August 31, 1937.

Exhibit B. Statement of Cash Receipts and Disbursements, General Fund, for the Year ended August 31, 1937.

We traced all recorded receipts to the depository bank, verified the general fund bank account and petty cash fund as at August 31, 1937 and examined properly approved vouchers for all disbursements.

We also verified by direct confirmation the balances of invested funds in the various savings bank accounts.

Respectfully submitted,
(Signed) Scovell, Wellington & Company.

EXHIBIT A

Statement of Assets and Funds

As at August 31, 1937.

Assets.

Cash in Banks, Invested Funds:		
City Five Cents Savings Bank, Haverhill, Mass.	$2 000.00	
Farmers and Mechanics Savings Bank, Framingham, Mass.	2 068.46	
Franklin Savings Bank, Boston, Mass.	2 000.00	
Haverhill Savings Bank, Haverhill, Mass.	2 000.00	
Home Savings Bank, Boston, Mass.	311.25	
Mechanics Savings Bank, Reading, Mass.	2 000.00	
Pentucket Savings Bank, Haverhill, Mass.	2 000.00	
Peoples Savings Bank, Worcester, Mass.	2 000.00	
Suffolk Savings Bank, Boston, Mass.	2 000.00	
Total Invested Cash		$16 379.71
General Fund:		
Cash, First National Bank of Boston	595.22	
Cash in Office	50.00	645.22
Furniture and Fixtures		1 180.00
		1 825.22
Total Assets		$18 204.93

Funds.

Invested Funds			$16 379.71
General Fund:			
Balance, August 31, 1936		$1 403.03	
Add: Addition to Furniture and Fixtures during Year	$ 66.50		
Excess of Receipts over Disbursements, Exhibit B	355.69	422.19	
Balance, August 31, 1937			1 825.22
Total Funds			$18 204.93

NOTE:—The above statement is prepared on a cash basis and does not reflect the following:

Accounts Receivable, Dues	$ 683.50
Due on Account of Advertising and other Miscellaneous Charges	474.14
	$ 1 157.64
Accounts Payable	$ 501.98
Dues and Subscriptions Paid in Advance	56.00
	$ 557.98

No Depreciation has been taken on Furniture and Fixtures.

EXHIBIT B

Statement of Cash Receipts and Disbursements.

General Fund.

For the Year ended August 31, 1937.

Receipts.

Initiation Fees		$ 256.00	
Dues		5 478.32	
Interest		449.48	
From Publication of Journal:			
Advertisements	$3 082.20		
Subscriptions	484.00		
Sale of Journal	79.75		
Sale of Reprints	901.28		
Sale of Halftones, Electros, etc.	4.50	4 551.73	
Miscellaneous:			
Membership Certificates	$ 16.50		
Receipts for Outing	553.85		
Miscellaneous	2.75	573.10	
Total Receipts			$11 308.63

Disbursements.

Publication of Journal:			
Printing	$3 082.23		
Plates	526.65		
Reporting	139.69		
Reprints	665.50		
Stationery and Postage	118.38		
Editor's Salary	500.00		
Sundries	8.41	$5 040.86	
Office and General:			
Certificate of Membership	$ 11.51		
Secretary's Salary (1935–1936)	400.00		
Assistant Secretary's Salary	1 344.50		
Secretary's Expense	20.65		
Treasurer's Salary (1935–1936)	100.00		
Treasurer's Bond	5.00		
Printing, Postage and Stationery	321.66		
Office Rent	1 200.00		
Electricity	27.40		
Telephone and Telegraph	130.49		
Audit	65.00		
Exchange	2.41		
Sundries	205.82	3 834.44	
Forward		$8 875.30	

Brought Forward		$8 875.30	
Meetings and Committees:			
Badges	$ 50.83		
Water Works School	77.25		
Printing, Postage and Stationery	610.59		
Stereopticon	155.00		
Committee Expense	99.52		
Convention Expense	429.96		
Outing Expense	560.38		
Miscellaneous Expense	94.11	2 077.64	
Total Disbursements			10 952.94
Excess of Receipts over Disbursements, Exhibit A			$355.69
Balance, General Cash, August 31, 1936			289.53
Balance, General Cash, August 31, 1937:			
Represented by, Cash in General Bank Account		$ 595.22	
Cash in Office		50.00	
			$ 645.22

Annual Report of the Editor.

To the New England Water Works Association: The Editor submits herewith the following report for the year ending August 31, 1937.

As has been customary in the past, the tables of financial figures, accompanying the report, are based upon total charges and accounts receivable, rather than actual cash received or disbursed. A detailed statement of the receipts and disbursements on account of the September and December, 1936, and March and June, 1937, issues of the Journal is included in the Report of the Treasurer.

Table 1 is a statement of the material published.

Table 2 gives a comparison of the Journal for the past year with preceding years.

Size. The four issues contained 627 pages, of which 435 were text.

Cost. The gross cost of the Journal was $5 040.86, equivalent to $6.53 per member; the net cost was $489.13, equivalent to $0.63 per member.

Reprints. Reprints of each paper have been furnished to the author at cost.

Circulation. The present circulation of the Journal is:

Members, all grades	783
Subscribers	121
Exchanges	16
Total	920

(Journals have been sent to all subscribers.)

Respectfully submitted,
Gordon M. Fair, *Editor.*

Table 1.

Statement of Material in September and December, 1936, and March and June 1937, Issues of the Journal of the New England Water Works Association.

Date.	Pages of.								
	Papers.	Proceedings.	Total Text.	Index.	Advertisements.	Cover and Contents.	Insert Plates.	Total.	Total Cuts.
September, 1936	96	0	96	0	41	5	3	145	25
December, 1936	78	26	104	9	43	5	1	153	22
March, 1937	125	6	131	0	43	5	0	179	19
June, 1937	101	3	104	0	41	5	0	150	39
Total	400	35	435	9	168	20	4	627	105

TABLE 2.

COMPARISON OF JOURNALS OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

	FOUR ISSUES FOR FISCAL YEAR ENDING AUG. 31.									
	1928.	1929.	1930.	1931.*	1932.	1933.	1934.	1935.	1936.	1937.
Average edition (copies printed)	1 138	1 200	1 350	1 260	1 200	1 125	1 100	1 100	1 100	1 100
Average membership	808	831	822	816	813	805	796	786	770	772
Circulation at end of year	955	993	980	955	957	930	928	918	903	940
Pages of text	528	507	570	410	437	420	499	470	477	435
Pages of text per 1 000 members	654	610	693	502	537	522	627	598	619	561
Total pages, all kinds	769	745	812	682	644	594	645	643	642	627
Total pages per 1 000 members	952	896	988	836	790	738	811	808	834	812
GROSS COST:										
Total	$6 849.44	$6 740.87	$8,054.59	$6 135.33	$5 024.03	$4 712.16	$5 411.30	$4 780.75	$5 880,68	$5 040.86
Per page	8.91	9.06	9.92	9.00	7.80	7.93	8.39	7.54	9.16	8.04
Per member	8.48	8.12	9.80	7.52	6.18	5.85	6.80	6.08	7.64	6.53
Per member per 1 000 pages	11.02	9.77	12.07	9.00	9.62	9.85	10.53	9.46	11.89	10.41
Per member per 1 000 pages text	16.06	16.01	17.19	18.34	14.30	13.94	13.62	12.93	16.01	15.01
NET COST:										
Total	$1 716.25	$1 857.58	$3 664.76	$1 252.21	$1 121.20	$1 176.77	$1 916.27	$1 332.99	$1 499.58	$489.13
Per page	2.23	2.07	4.51	1.84	1.74	1.98	2.97	2.07	2.34	0.78
Per member	2.12	2.24	4.46	1.53	1.38	1.46	2.41	1.70	1.95	0.63
Per member per 1 000 pages	2.76	2.50	5.49	2.24	2.14	2.46	3.73	2.64	3.03	1.01
Per member per 1 000 pages text	4.02	4.41	7.82	3.73	3.16	3.48	4.83	3.61	4.08	1.46

*Including comprehensive index, 1882 to 1930.

Report of Finance Committee.

To the Executive Committee of the New England Water Works Association:

Gentlemen: The Finance Committee submits the following budget for the fiscal year ending August 31, 1938.

Journal	$5 500
Office	4 000
Meetings and Committees	1 500
Total	$11 000

In view of the general better business outlook, the increased receipts from the Journal advertising and an increased membership, a slightly increased budget has been recommended in order to provide funds, without exceeding the estimated receipts for the year, for the committees on new members, on library and quarters and on grounding of water pipes as well as adequate funds for the Journal.

In preparing the budget, the expenditures for the past eleven years were utilized and it was observed that apparently expenditures are not always correctly allocated to one of the above classifications, making comparative study difficult, nor is section seven of the constitution followed regarding expenditures exceeding the adopted budget. Attention to these matters would, no doubt, overcome the practice of carrying over into the fiscal year, expenses that make for annual deficits.

An audit of the books has been made by a Certified Public Accountant, whose report is made part of the Treasurer's Report.

(Signed) William B. Duffy,
Donald C. Calderwood,
Harold L. Brigham.

August 23, 1937.

Progress Report of the Committee on the Advisability of Water Departments Regulating Water Piping and Fixtures within Buildings.

The Committee appointed for the study of "The Advisability of Water Departments Regulating Water Piping and Fixtures within Buildings" has made a study of various phases of the problems relating to house plumbing, and at the November 19, 1936, meeting of This Association under the guidance of Stephen H. Taylor, Chairman, presented a program as follows:

Address with visual educational films illustrating siphonic action on contaminated water through cross-connections or faulty plumbing by E. L. Penfrase, Copper and Brass Research Association, New York City.

Discussion of the Report:

Attitude of Privately Owned Water Companies, M. Warren Cowles, Health Officer, Hackensack Water Company, New Milford, N. J.

Attitude of Master Plumbers, John J. Downey, President, Massachusetts State Association of Master Plumbers.

Safety Devices for Water-Heating Apparatus, Ernest G. Parker, Inspector of Plumbing, Health Department, New Bedford, Mass.

Types of Fixtures with Reference to Contamination by Back-Siphonage, Leslie K. Sherman, Assistant Engineer, State Department of Health, Hartford, Conn.

Special Equipment, Arthur V. Harrington, Assistant Engineer, Massachusetts Department of Public Health, Boston, Mass.

Storage Tanks, Henry E. Halpin, Engineer, Associated Factory Mutual Fire Insurance Companies, Boston, Mass.

Electric Grounding on Water Pipes, J. O. R. Coleman, Edison Electric Institute, New York City.

Size, Location and Materials used for Service, Stephen H. Taylor, Superintendent, Water Works, New Bedford, Mass.

These topics were presented for discussion at the meeting held December 17, 1936, after which the Committee was instructed to continue its work and prepare such recommendations as were deemed advisable to make to the Association.

The study made by your Committee shows that—

1. There are many types of unprotected cross-connections found even in the average community which is made up largely of dwellings;

2. the industrial plants and certain municipal establishments present an entirely different problem in many instances;

3. there are a great number of devices, fixtures and special equipment which are offered for sale which, by inherent construction and without proper protection, present a hazardous condition when placed into service.

It has been definitely proved that most of the safety devices which are in use for the protection of water-heating apparatus and storage tanks are not adequate, subjecting householders to a very considerable explosion hazard in certain instances. Moreover, the water department and con-

sumer is concerned because of "cooked" meters which result from the lack of proper protection or through faulty operation of existing protective devices.

It was shown that under certain conditions, the type, size and materials used for service pipes have been the primary cause of setting up negative pressure within a building, which in turn presented a hazardous condition where the water supply pipes on the same system were connected to fixtures, devices or equipment which by their construction could readily be siphoned.

It has been indicated that the practice of grounding of electric circuits on water piping is detrimental to water supply piping, in that electrolytic corrosion is established and that possibly deterioration of the water may result. An examination of Section 909f of the National Electrical Code shows that good practice for electrical installations, which furnish power and light, calls for grounding on the street side of the meter, or that a permanent bond be provided around the meter and its connections. This code does not make the same requirements for grounding of telephone and radio circuits. There have been cited several instances of temporary injury to water works employees by shock resulting while removing meters and otherwise when the metallic ground circuit has been opened.

Experience of one private company, as discussed in the symposium, has shown what can be done by private water companies in the matter of inspections and follow up of a cross-connection program through the efforts of the existing personnel of the concern.

Representatives of the plumbing profession have indicated their willingness to coöperate in efforts to educate the public and do their share in an endeavor to induce manufacturers to supply the trade with fixtures and devices which will provide the householder and industry with more adequate protection against pollution by back siphonage or improper material and sizes of water piping.

It is the consensus of opinion of your committee that it would be unwise to recommend any wholesale program of inspection of existing plumbing facilities, as it would probably build up a resistance and antagonism by the public which would defeat the purpose. It is thought, however, that the various existing public agencies can do much to correct a situation which will not improve unless definite action is taken.

We believe that the superintendent, or other officer responsible for purity of water supply, should interest himself and should either assume this responsibility or, lacking this authority, should initiate such procedure to the end that proper regulations to maintain the safety of the water supply within buildings are made and enforced.

A good start might be to inaugurate a system of inspection of new work which could eventually be extended to cover the more important existing situations.

The NEW ENGLAND WATER WORKS ASSOCIATION on December 12, 1928, adopted a resolution as follows:

WHEREAS, evidence shows that the existence of certain cross-connections between safe public water supplies and unsafe private water supplies, not equipped with modern protective devices, has resulted in many outbreaks of disease and many deaths, and

WHEREAS, such cross-connections are a hazardous part of any water-supply system.

1. This Association recommends that no cross-connections be permitted with a supply that in the opinion of the state health authorities is bacterially unsafe.

2. This Association recommends that any cross-connection permitted with a bacterially safe but non-potable supply shall be made through a properly installed and adequately supervised, all-bronze, rubber-seated, double check-valve of a type approved by the state health authorities."

In furtherance of the aims set forth in this resolution and having in mind the potential hazards caused by water supply connections which are of improper material and inadequate size to furnish an ample supply of water within buildings to devices, fixtures, tanks and household appliances which are not subject to examination or inspection of any local authority, your Committee now proposes this additional resolution for adoption by the NEW ENGLAND WATER WORKS ASSOCIATION:

BE IT RESOLVED in the interest of protection of the health and safety of water consumers and the safety of workmen engaged in water works maintenance:

1. That This Association place itself on record as being opposed to the existence of any form of unprotected cross-connection between pipes carrying water for drinking and pipes carrying water of questionable quality or carrying sewage or other liquid of a quality or substance unfit for human consumption.

2. That This Association urge that power be delegated to the proper authority in each municipality, acting under state regulations, whose duty it shall be to make and enforce proper rules governing the installation of pipes and fixtures within buildings, examine plans and specifications for new installations and to inspect the completed work in place, having authority to approve or reject any device, fixture, pipe size or material, connection, valve or accessory as may be necessary in order to provide proper protection against pollution by cross-connections or back-siphonage and assure that pipes of proper size to furnish an adequate supply of water to fixtures are installed.

3. That This Association recognize that proper safety appliances should be provided to protect hot-water heating systems and to reduce the possibilities of damage to meters on many existing installations.

4. That This Association recommend, pending further information on the subject of deterioration of water quality or of danger to occupants of buildings because of electric grounding on water pipes, that section 909f of the National Electrical Code be followed with reference to grounding of light and power circuits within a building on the street side of the meter and that a permanent metallic circuit be provided around any meter and its connections, both of which precautions will greatly reduce possible effect of electrical currents insofar as they may cause deterioration of water pipes or produce dangerous shocks.

5. That This Association request the coöperation of all manufacturers, architects and designers in preventing the manufacture or installation of improper plumbing, hospital equipment, and improperly protected hot-water tank equipment and devices by eliminating the production of the same through the preparation of such specifications as will eliminate faulty equipment and improper connections.

6. That This Association continue to coöperate with the American Water Works Association, the American Public Health Association and others in an endeavor to reduce the hazards of cross-connections in any form.

Your Committee is pleased that the Executive Committee of this Association voted to join with the American Water Works Association, the Master Plumbers Association, Conference of State Sanitary Engineers and American Public Health Association to form a National Inter-Association Committee on Cross-Connections which met at Buffalo, New York, on June 9, 1937, proceeded to elect a permanent Chairman and outlined a procedure in keeping with this report.

(Signed) STEPHEN H. TAYLOR, *Chairman.*
HARRY U. FULLER.
DAVID A. HEFFERNAN.
WARREN J. SCOTT.
ARTHUR V. HARRINGTON.

JOHN CARROLL CHASE.

John Carroll Chase, one of the most loyal members of the NEW ENGLAND WATER WORKS ASSOCIATION, died at Brookline, Mass., on April 15, 1936, after an illness of three months. His affiliation with the Association extended from 1884, two years after its organization, until his death, a span of 52 years.

He was born July 26, 1849, at Chester, N. H., of Charles and Caroline (Chase) Chase and was a direct descendant on both sides from Aquila Chase who settled at Hampton, N. H. in 1640. His education, begun in the district school, was continued in the Chester Academy, the Pinkerton Academy at Derry, N. H., and the Massachusetts Institute of Technology, Class of 1874. For a time, in his early manhood, he taught school at West Newbury, Mass.

He began his professional career as a civil engineer in the office of Joseph B. Sawyer of Manchester, N. H. and, after leaving Technology, was employed for nearly four years as an assistant engineer in the construction of the Manchester Water Works. He then became an assistant engineer on the construction of the Sudbury Aqueduct of the Boston Water Works and when that work was finished served a few years as assistant engineer on the Elevated Railway Systems of New York City. In 1880, he became assistant cashier in the Naval Service of the New York Custom House. He resigned from the federal service in 1881 and became Superintendent and Engineer of the Clarendon Water Works Company at Wilmington, N. C., being promoted to Chief Engineer in 1895 from which position he resigned in 1897. During his connection with the Clarendon Water Works Company he practiced as a civil engineer, served as City Surveyor for Wilmington and was Engineer Member of the North Carolina State Board of Health for four years.

In 1897, after his resignation at Wilmington, he returned to Derry, N. H., where he became connected with a manufacturing business established there by his mother's brother. When this business was incorporated in 1907 he became Treasurer and General Manager and in 1909 became President as well as Treasurer. These two offices were held by him until his death.

Although Mr. Chase gave up the practice of professional engineering nearly forty years before his death, his interest in the profession remained active, particularly as it related to water works. He was a faithful attendant at meetings of technical and professional societies and frequently participated in discussions of papers. He was a contributor to the JOURNAL of This Association in its early days. Besides his membership in the NEW ENGLAND WATER WORKS ASSOCIATION, he was a member of both the American and Boston Societies of Civil Engineers, and a Fellow of the American Public Health Association.

His interest in genealogical matters was keen, and he had been president of the New England Historic Genealogical Society since 1921. He was also a member of the New Hampshire Historic Society, a member of the Governing Board of the Massachusetts Society of the Sons of the American Revolution, Deputy Governor and Deputy Governor General of the Society of Colonial Wars in New Hampshire, and a member of other similar societies. He was one of the founders and for many years President of the Chase-Chace Family Association.

Among his clubs were the City, University, and Appalachian Mountain Clubs of Boston, the Technology Club of New York and the University Club of San Diego, California. He was a member of the Alumni Council of the Massachusetts Institute of Technology. He was a Republican, Knight Templar and an Odd Fellow.

He married Mary Lizzie Durgin of West Newbury, Mass., in 1871 who died in 1927 and by whom he had two daughters who survive him, Mrs. Raffaele Lorini (Caroline Louise Chase) and Mrs. Samuel C. Prescott (Alice Durgin Chase). He was married a second time to Florence Anne Buchanan at Vancouver, B. C., in 1928, who also survives him.

The foregoing outline of Mr. Chase's life shows clearly the multiplicity of his activities and the breadth of his interests. His friend, Robert Lincoln O'Brien, referring to Mr. Chase's travels comments as follows:

> "On such journeys he visited the great engineering projects which might be in the making, observing them with a keen professional insight and interest. In this way he kept fully abreast of the progress of civil engineering, for he always remained an engineer at heart, even though engrossed in the problems of business or the preparation of his books and papers dealing with historical research. To him travel was not merely a means of translocation; it was a constant widening of his horizon, a source of new knowledge and real education. This in part may explain his singular young-mindedness, for his outlook when long past four-score was essentially that of a man in the prime of life."

The accuracy of Mr. O'Brien's comments will be appreciated by all members of This Association who were privileged to know Mr. Chase.

New England to the core, by descent and temperament, Mr. Chase lived an abundant life, active, keen of mind, friendly, of broad cosmopolitan interests and of sterling character. His life may well have been guided by the Chase motto "Ne Cede Malis."

E. Sherman Chase.

HARRISON PRESCOTT EDDY.

Harrison Prescott Eddy, a member of the New England Water Works Association since 1894 and an honorary member for the last eight years, died suddenly from a heart attack on June 15, 1937, in Montreal where he had gone to receive honorary membership in The Engineering Institute of Canada at its semi-centennial meeting. Mr. Eddy was Senior Partner of the firm of Metcalf & Eddy, Engineers, Statler Building, Boston, and his home address was 65 Gray Cliff Road, Newton Centre. He was a leader of the civil engineering profession and dean of the sanitary engineers in America.

Mr. Eddy was born in Millbury, Massachusetts, on April 29, 1870. His parents were William Justus and Martha Augusta (Prescott) Eddy. His earliest paternal ancestor in this country was John Eddy, born in March, 1597 at Boxted, Suffolk County, England, who came to Plymouth in 1630 and settled in Watertown. On June 1, 1892, Mr. Eddy married Minnie Locke Jones of Worcester, who survives him. Their children were Willard Jones Eddy (deceased), Harrison Prescott Eddy, Jr., now of Medfield, Randolph Locke Eddy of Newton, and Charlotte Frances Eddy, now Mrs. Charles W. Eaton of Newton. Mr. Eddy also leaves two brothers, Ernest Justus Eddy of Hartford, Connecticut, and William Clifton Eddy of Houghton, Michigan.

Mr. Eddy was educated in the public schools of Worcester, graduating from the high school in 1888; and at the Worcester Polytechnic Institute, from which he graduated in 1891 with the degree of Bachelor of Science in the Course in Chemistry under the late Professor Leonard P. Kinnicutt, Sc.D., a sanitary chemist of international reputation.

While at the Worcester Polytechnic Institute, Mr. Eddy worked during summer vacations in the Worcester City Engineer's Department, and upon graduation was employed by the city as Chemist and shortly afterwards was made Superintendent of the Sewage Purification Works which was then the largest sewage treatment plant in this country. After about a year in this position he was elected Superintendent of the Sewer Department, a position which he held for 15 years, until he resigned in 1907.

During his early years in Worcester, Mr. Eddy's natural aptitude for research was greatly stimulated by continued contact with Dr. Kinnicutt. Mr. Eddy was also fortunate at that time in meeting the most eminent sanitary engineers and chemists in this country and abroad. His first trip to Europe was made in 1894. His early association, in several litigation cases, with City Solicitor Arthur P. Rugg, now Chief Justice of the Massachusetts Supreme Court, was also of great importance and laid the foundation for Mr. Eddy's valuable service as expert witness in many important cases.

During his service as Superintendent of the Sewer Department of Worcester, Mr. Eddy had supervision of the construction, operation and maintenance of the sewer system and of the sewage treatment works. All construction, including the manufacture of many tools, machines and other equipment used upon the work, was done by force account. Research, particularly in the field of sewage treatment, was carried on under Mr. Eddy's direction almost continuously in the laboratory and on a plant scale at the Worcester sewage works. During this period Mr. Eddy was frequently consulted by the Water Commissioner and the City Engineer of Worcester on local water supply problems, and his services in a consulting capacity were increasingly sought by others outside of Worcester.

In May, 1907, Mr. Eddy joined with Leonard Metcalf of Boston, to form the partnership of Metcalf & Eddy, Consulting Engineers, specializing in problems relating to water, sewage, industrial wastes and municipal refuse. The firm rapidly gained a national reputation and was increasingly engaged upon work of large magnitude all over the country. Following the death of Mr. Metcalf in January, 1926, Mr. Eddy formed a new partnership, having the same name, with seven of his associates.

During the last thirty years Mr. Eddy acted as Consulting Engineer on numerous problems of water supply, water purification, sewerage and drainage, treatment of sewage and of industrial wastes, disposal of municipal refuse, flood control, and allied services. These problems have involved preliminary investigations and reports and design, supervision of construction and supervision of operation, of works costing many millions of dollars. In one or more of these capacities Mr. Eddy served more than 100 municipalities and many private concerns including water companies and industries.

The important engagements of Mr. Eddy are too numerous to describe here. The large cities which he served in a consulting capacity include the following: Akron, Allentown, Boston, Brooklyn, Buffalo, Chicago (Sanitary District), Cincinnati, Cleveland, Dayton, Detroit, El Paso, Fort Wayne, Hartford, Los Angeles (Metropolitan Water District of Southern California), Louisville, Miami, New Orleans, New York, Pittsburgh, Portland (Oregon), Rochester, San Antonio, San Francisco, Schenectady, Springfield (Massachusetts), Syracuse, Toronto and Washington, D. C.

In addition to his consulting work in an individual capacity, Mr. Eddy served on numerous engineering boards or commissions, notably the Engineering Board of Review, consisting of 28 engineers appointed by the Sanitary District of Chicago in 1924, to consider the lake-lowering controversy and to report remedial measures. He was chairman of the subcommittee which investigated the sewage disposal problem of Chicago and reviewed plans and recommended construction of sewerage works estimated to cost $125,000,000. Mr. Eddy was a member of the Technical Board of Review appointed by the Federal Public Works Administration in 1935, to pass upon public works projects, and one of a board of consulting en-

gineers appointed by the Tennessee Valley Authority in 1936, to advise on problems of flood relief in the Tennessee River Valley.

At the time of his death, Mr. Eddy was one of the consulting engineers to the New York Board of Water Supply, upon the Delaware River project. He was also serving as one of the consultants to the Water Resources Service of the Department of Forests and Waters of the State of Pennsylvania, relative to water supply for Pittsburgh, Harrisburg and Philadelphia.

Mr. Eddy served as expert witness in numerous cases including the following adjudicated by the United States Supreme Court: New York *versus* New Jersey, relative to the proposed discharge of Passaic Valley sewage into New York Harbor; Wisconsin *et al. versus* the State of Illinois and the Sanitary District of Chicago, relative to the disposal of the sewage of Chicago; New Jersey *versus* New York, relative to the taking of Delaware River water for additional water supply for New York City; Connecticut *versus* Massachusetts, relative to the taking of water from the Ware and Swift Rivers for additional water supply for the Boston Metropolitan District. Mr. Eddy was also called to testify in the celebrated activated sludge patent suit brought against the city of Milwaukee.

Mr. Eddy was co-author (with Leonard Metcalf) of "American Sewerage Practice" in three volumes, published in 1914 and 1915, and "Sewerage and Sewage Disposal — A Textbook," published in 1922, all except the second volume of the former having been revised by Mr. Eddy since Mr. Metcalf's death. These are standard works.

In addition to numerous reports to clients Mr. Eddy contributed many papers to professional societies and the technical press. In this connection, the Boston Society of Civil Engineers awarded him the Desmond Fitzgerald Medal in 1920 for his paper on "Maximum Rates of Precipitation at Boston for Various Frequencies of Occurrence," and the American Society of Civil Engineers awarded him the Norman Medal in 1925 and the Rudolph Hering Medal in 1927 for his paper on "Imhoff Tanks — Reasons for Differences in Behaviour," the Norman Medal being the highest literary distinction in the profession.

It may also be of interest to note that under the auspices of the Science Advisory Committee of the National Research Council coöperating in the Chicago World Fair Centennial Celebration, Mr. Eddy on May 27, 1931, presented a radio broadcast entitled "A Century of Progress in Water Purification," a paper based on this radio address having been published in "Civil Engineering" for February, 1932. Mr. Eddy's last paper, which was on "The Next Fifty Years," was posthumously delivered at a meeting of The Engineering Institute of Canada on June 16, 1937, and was published in "Civil Engineering" for August, 1937, and has been widely referred to and quoted.

Mr. Eddy was a member of numerous technical societies in addition to the New England Water Works Association, including the Boston Society of Civil Engineers of which he was President in 1914, American Society of Civil Engineers of which he was President in 1934, American

Institute of Consulting Engineers, of which he was Vice-President in 1926, American Chemical Society, American Water Works Association, American Public Health Association of which he was a Fellow, American Society for Testing Materials, The Engineering Institute of Canada of which he was made an Honorary Member, The Institution of Civil Engineers of Great Britain and The Institution of Sanitary Engineers of Great Britain, of which he was Honorary Fellow.

Mr. Eddy received the honorary degree of Doctor of Engineering from the Worcester Polytechnic Institute in 1930, and a similar degree from the Northeastern University in 1931. At the time of his death Mr. Eddy was a Trustee of the Worcester Polytechnic Institute.

The clubs of which Mr. Eddy was a member included the Engineers Club of Boston, the Engineers Club of New York, the Braeburn Country Club of Newton and The Neighbors of Newton Centre. He had also been a member of the Union Club of Boston, the University Club, the Pocasset Golf Club and the Boston and Beverly Yacht Clubs.

The outstanding characteristics of Mr. Eddy, which carried him to the pinnacle of his profession included exceptional ability to grasp new problems, great power of concentration, enormous capacity for hard work, thoroughness in investigation, sound judgment and zeal for rendering service of the highest quality. He was an engineer of broad vision, but he had an analytical mind and a judicial temperament. He had unusual ability to utilize previously gained knowledge and experience in the solution of the problem at hand. He was conservative with respect to innovations, but progressive in well founded developments. He could not be stampeded by persuasive but unsubstantiated arguments.

Mr. Eddy was a clear writer and a forceful and convincing speaker with excellent poise and self-control. He had the faculty of explaining to the layman in simple language the most complicated technical matters.

Mr. Eddy was a man of high ideals and high moral standards. He referred to professional ethics as "the application of the Golden Rule." One of his chief attributes was kindness. He was characterized by his thoughtful consideration of the welfare of his subordinates and by his helpful advice to young engineers and chemists all over the country. His character was noble, his counsel wise, and his friendship true. He endeared himself to all who were privileged to know him. He had a host of friends inside and outside the engineering profession. He was a gentleman of the first rank, a delightful companion and a gracious host.

Afflicted for a number of years with an incurable heart ailment, Mr. Eddy carried on without flinching, and few knew of his physical handicap. Because of his activity up to the last, his death came as a great shock.

In the death of Mr. Eddy, the New England Water Works Association has lost a most distinguished member, and the country a most eminent engineer. His high character and great ability have made a deep impression on the engineering profession, and his influence will continue to be felt.

ALMON L. FALES,
FRANK A. BARBOUR.

JOURNAL

OF THE

New England Water Works Association

VOLUME LI

1937

PUBLISHED BY

THE NEW ENGLAND WATER WORKS ASSOCIATION

613 STATLER BUILDING, BOSTON, MASS.

The four numbers composing this volume have been
separately copyrighted in 1937
by the New England Water Works Association.

AUTHOR INDEX

Adams, George O. and Francis H. Kingsbury. Experiences with Chlorinating New Water Mains. 60, Mar.

Almquist, Frederick O. A. Water Chlorination Experience. 41, Mar.

Baylis, John R. Filter Bed Troubles and their Elimination. 1, Mar.

Blakeley, Gerald W. Transite Pipe. 317, Sept.

Boyd, George E. Development and Use of Spun Bituminous Coatings for Water Pipe in the United States. 393, Dec.

Brigham, Harold L. Our Introduction to Transite Pipe. 285, Sept.

Byers, Horace R. Meteorological Conditions During the March, 1936 and other Notable Floods. 210, June.

Byers, Horace R., Montrose W. Hayes and. Some Flood-Producing Storms of the Atlantic Seaboard. 207, June.

Casagrande, Arthur. Seepage Through Dams. 131, June.

Chase, John Carroll. Obituary. 480, Dec.

Cline, A. C. Silvicultural Aids in the Control of Gypsy Moth in Watershed Forests. 235, Sept.

Coleman, J. O. K. Electric Grounding on Water Pipes. 277, Sept.

Committee on Advisability of Water Departments Regulating Water Piping and Fixtures within Buildings. Progress Report. 259, Sept. 476, Dec.

Cowles, M. W. What Interest has a Water Purveyor in Interior Plumbing Systems in Relation to Cross-Connections. 261, Sept.

Dappert, Anselmo F. Public Health Aspects of the Flood of March, 1936 in New York State. 69, Mar.

Eddy, Harrison Prescott. Obituary. 482, Dec.

Esty, Roger W. Sizes of Meters for Services. 245, Sept.

Field, H. L. Construction of a Modified Slow Sand-Filtration Plant at Greenfield, Mass. 173, June.

Fuller, Harry U. Portrait of President. Frontispiece, Mar. Presidential Address. 461, Dec.

Gilcreas, F. Wellington. The Influence of Dissolved Oxygen in Accelerating the Corrosive Action of Water. 380, Dec.

Griswold, Harold W. Master Meters. 203 June.

Hale, Frank E., Robert Shapiro and. An Investigation of the Katadyn Treatment of Water with Particular Reference to Swimming Pools. 113, Mar.

Halpin, H. E. Tanks for Water Service in High Buildings. 273 Sept.

Harrington, Arthur V. Special Equipment Cross-Connections. 270, Sept.

Hayes, Montrose W. and Horace R. Byers. Some Flood-Producing Storms of the Atlantic Seaboard. 207, June.

Howard, Paul F. Experiences with Low-velocity Gravel-packed wells. 424, Dec.

Johnson, Robert P. Operating Experiences at the Salem and Beverly Filtration Plant. 185, June.

King, Arthur C. Rigid versus Flexible Service Connections. 111, Mar.
Kingsbury, Francis H., George O. Adams and. Experiences with Chlorinating New Water Mains. 60, Mar.

Lumbert, Wm. J. Transite for Wells and Screens. 310, Sept.

MacKenzie, Samuel H. Factors to be Considered in Determining the Size of Mains and Services. 108, Mar. Size of Meters for Services. 367, Dec.
Marston, Frank A. Transite Pipe River Crossing at Scituate, Mass. 299, Sept.
McCurdy, H. S. R. Operating Experience with Anthracite Filters. 37, Mar.
Mitchell, J. Development and Use of Spun Bituminous Coating for Water Pipes in Great Britain. 390, Dec.
Moulton, David E. Address of Welcome. 455, Dec.
Meeting the Demand for Recreation Facilities near Public Water Supplies. 370, Dec.
Morehouse, W. W. Development of the Ground Water Supply of the City of Dayton, Ohio. 219, June.

Pirnie, Malcolm. Some Operating Experiences with Iron Coagulants. 437, Dec.

Rich, A. B. Experience with Transite Pipe. 289, Sept.

Saville, Caleb Mills. New England Droughts and Floods. 326, Sept.
Scott, Warren J. Qualifications of Operators of Water Treatment Plants. 403, Dec.
Shapiro, Robert and Frank E. Hale. An Investigation of the Katadyn Treatment of Water with Particular Reference to Swimming Pools. 113, Mar.
Sherman, Charles W. Underwriters Tests of Transite Pipe. 282, Sept.
Sherman, Leslie K. Plumbing Fixtures Subject to Back-Siphonage. 266, Sept.
Sigworth, E. A. Activated Carbon. 200, June.
Smith, Fred E. Chlorination of a Cambridge Main. 57, Mar.
Snow, Bayard F. The Needham Gravel-packed Well. 409, Dec.
Spear, Walter E. Additional Water Supply for the City of New York. 227, June.
Stevenson, W. L. Public Health Aspects of the Flood of March, 1936 in Pennsylvania. 80, Mar.

Waring, F. H. The Ohio Flood of 1936. 103, Mar.
Wentworth, John P. Additional Ground Water Supply for Woburn, Mass. 430, Dec.
Weston, Arthur D. Public Health Aspects of the Flood of March, 1936 in Massachusetts. 90, Mar.
Weston, Robert Spurr. Neutralization of Corrosive Action. 384, Dec.
Water Supply of Northborough, Mass., and its Improvement. 248, Sept.
Whipple, M. C. The Corrosion Problem in Cambridge, Mass. 376, Dec.

SUBJECT INDEX.

Activated Carbon. By E. A. SIGWORTH. 200, June.
Additional Ground Water Supply for Woburn, Mass. By JOHN P. WENTWORTH. 430, Dec.
Additional Water Supply for the City of New York. By WALTER E. SPEAR. 227, June.
Advisability of Water Departments Regulating Water Piping and Fixtures Within Buildings. PROGRESS REPORT OF COMMITTEE. 259, Sept. 476, Dec.
Anthracite Filters, Operating Experience with. By H. S. R. MCCURDY. 37, Mar.
Atlantic Seaboard, Some Flood-Producing Storms of the. By MONTROSE W. HAYES and HORACE R. BYERS. 207, June.

Back-Siphonage, Plumbing Fixtures Subject to. By LESLIE K. SHERMAN. 266, Sept.
Beverly Filtration Plant, Operating Experiences at the Salem and. By ROBERT P. JOHNSON. 185, June.
Bituminous Coating for Water Pipes in Great Britain, Development and Use of Spun. By J. MITCHELL. 390, Dec.
Bituminous Coatings for Water Pipe in the United States, Development and Use of Spun. By GEORGE E. BOYD. 393, Dec.

Cambridge Main, Chlorination of a. By FRED E. SMITH. 57, Mar.
Cambridge, Mass., The Corrosion Problem in. By M. C. WHIPPLE. 376, Dec.
Carbon, Activated. By E. A. SIGWORTH. 200, June.
Chlorinating New Water Mains, Experiences with. By GEORGE O. ADAMS and FRANCIS H. KINGSBURY. 60, Mar.
Chlorination Experience, Water. By FREDERICK O. A. ALMQUIST. 41, Mar.
Chlorination of a Cambridge Main. By FRED E. SMITH. 57, Mar.
Coagulants, Some Operating Experiences with Iron. By MALCOLM PIRNIE. 437, Dec.
Coating for Water Pipes in Great Britain, Development and Use of Spun Bituminous. By J. MITCHELL. 390, Dec.
Coatings for Water Pipe in the United States, Development and Use of Spun Bituminous. By GEORGE E. BOYD. 393, Dec.
Construction of a Modified Slow Sand-Filtration Plant at Greenfield, Mass. By H. L. FIELD. 173, June.
Corrosion Problem in Cambridge, Mass., The. By M. C. WHIPPLE. 376, Dec.
Corrosive Action, Neutralization of. By ROBERT SPURR WESTON. 384, Dec.
Corrosive Action of Water, The Influence of Dissolved Oxygen in Accelerating the. By F. WELLINGTON GILCREAS. 380, Dec.
Cross-Connections, Special Equipment. By ARTHUR V. HARRINGTON. 270, Sept.
Cross-Connections, What Interest has a Water Purveyor in Interior Plumbing Systems in Relation to. By M. W. COWLES. 261, Sept.

Dams, Seepage through. By ARTHUR CASAGRANDE. 131, June.
Dayton, Ohio, Development of the Ground Water Supply of the City of. By W. W. MOREHOUSE. 217, June.
Development and Use of Spun Bituminous Coating for Water Pipes in Great Britain. By J. MITCHELL. 390, Dec.
Development and Use of Spun Bituminous Coatings for Water Pipe in the United States. By GEORGE E. BOYD. 393, Dec.
Development of the Ground Water Supply of the City of Dayton, Ohio. By W. W. MOREHOUSE. 219, June.

Dissolved Oxygen in Accelerating the Corrosive Action of Water, The Influence of. By F. WELLINGTON GILCREAS. 380, Dec.
Droughts and Floods, New England. By CALEB MILLS SAVILLE. 326, Sept.

Electric Grounding on Water Pipes. By J. O. K. COLEMAN. 277, Sept.
Experiences with Chlorinating New Water Mains. By GEORGE O. ADAMS and FRANCIS H. KINGSBURY. 60, Mar.
Experiences with Low-velocity Gravel-packed Wells. By PAUL F. HOWARD. 424, Dec.
Experience with Transite Pipe. By A. B. RICH. 289, Sept.

Factors to be Considered in Determining the Size of Mains and Services. By SAMUEL H. MACKENZIE. 108, Mar.
Filter Bed Troubles and their Elimination. By JOHN R. BAYLIS. 1, Mar.
Filters, Operating Experience with Anthracite. By H. S. R. MCCURDY. 37, Mar.
Filtration Plant at Greenfield, Mass., Construction of a Modified Slow Sand-. By H. L. Field. 173, June.
Filtration Plant, Operating Experiences at the Salem and Beverly. By ROBERT P. JOHNSON. 185, June.
Fixtures within Buildings, Advisability of Water Departments Regulating Water Piping and. PROGRESS REPORT OF COMMITTEE. 259, Sept. 476, Dec.
Flexible Service Connections, Rigid versus. By ARTHUR C. KING. 111, Mar.
Flood of March, 1936, Public Health Aspects of the:
New York State. By ANSELMO F. DAPPERT. 69, Mar.
Pennsylvania. By W. L. STEVENSON. 80, Mar.
Massachusetts. By ARTHUR D. WESTON. 90, Mar.
Flood of 1936, The Ohio. By F. H. WARING. 103, Mar.
Flood-Producing Storms of the Atlantic Seaboard, Some. By MONTROSE W. HAYES and HORACE R. BYERS. 207, June.
Floods, Meteorological Conditions During the March, 1936 and Other Notable. By HORACE R. BYERS. 210, June.
Floods, New England Droughts and. By CALEB MILLS SAVILLE. 326, Sept.
Forests, Silvicultural Aids in the Control of Gypsy Moth in Watershed. By A. C. CLINE. 235, Sept.

Gravel-packed Well, The Needham. By BAYARD F. SNOW. 409, Dec.
Gravel-packed Wells, Experiences with Low-velocity. By PAUL F. HOWARD. 424, Dec.
Greenfield, Mass., Construction of a Modified Slow Sand-Filtration Plant. By H. L. Field. 173, June.
Grounding on Water Pipes, Electric. By J. O. K. COLEMAN. 277, Sept.
Ground Water Supply for Woburn, Mass., Additional. By JOHN P. WENTWORTH. 430, Dec.
Ground Water Supply of the City of Dayton, Ohio, Development of the. By W. W. MOREHOUSE. 219, June.
Gypsy Moth in Watershed Forests, Silvicultural Aids in the Control of. By A. C. CLINE. 235, Sept.

Influence of Dissolved Oxygen in Accelerating the Corrosive Action of Water, The. By F. WELLINGTON GILCREAS. 380, Dec.
Investigation of the Katadyn Treatment of Water with Particular Reference to Swimming Pools, An. By ROBERT SHAPIRO and FRANK E. HALE. 113, Mar.
Iron Coagulants, Some Operating Experiences with. By MALCOLM PIRNIE. 437, Dec.

Katadyn Treatment of Water with Particular Reference to Swimming Pools, An Investigation of the. By ROBERT SHAPIRO and FRANK E. HALE. 113, Mar.

Low-velocity Gravel-packed Wells, Experiences with. By PAUL F. HOWARD. 424, Dec.

Main, Chlorination of a Cambridge. By FRED E. SMITH. 57, Mar.
Mains and Services, Factors to be Considered in Determining the Size of. By SAMUEL H. MACKENZIE. 108, Mar.
Mains, Experiences with Chlorinating New Water. By GEORGE O. ADAMS and FRANCIS H. KINGSBURY. 60, Mar.
Massachusetts, Public Health Aspects of the Flood of March, 1936 in. By ARTHUR D. WESTON. 90, Mar.
Master Meters. By HAROLD W. GRISWOLD. 203, June.
Meeting the Demand for Recreation Facilities near Public Water Supplies. By DAVID E. MOULTON. 370, Dec.
Meteorological Conditions During the March, 1936 and Other Notable Floods. By HORACE R. BYERS. 210, June.
Meters for Services, Sizes of. By ROGER W. ESTY. 245, Sept.
Meters for Services, Size of. By SAMUEL H. MACKENZIE. 367, Dec.
Meters, Master. By HAROLD W. GRISWOLD. 203, June.
Modified Slow Sand-Filtration Plant at Greenfield, Mass., Construction of a. By H. L. FIELD. 173, June.
Moth in Watershed Forest, Silvicultural Aids in the Control of Gypsy. By A. C. CLINE. 235, Sept.

Needham Gravel-packed Well, The. By BAYARD F. SNOW. 409, Dec.
Neutralization of Corrosive Action. By ROBERT SPURR WESTON. 484, Dec.
New England Droughts and Floods. By CALEB MILLS SAVILLE. 326, Sept.
New England Water Works Association.
Address of President. By HARRY U. FULLER. 461, Dec.
Address of Welcome. By DAVID E. MOULTON. 455, Dec.
Dexter Brackett Memorial Medal Award. 457, Dec.
Election of Officers. 461, Dec.
Proceedings:
November, 1936, Meeting. 125, Mar.
December, 1936, Meeting. 127, Mar.
January, 1937, Meeting. 128, Mar.
February, 1937, Meeting. 129, Mar.
March, 1937, Meeting. 232, June.
April, 1937, Meeting. 233, June.
March, 1937, Meeting. 234, June.
Fifty-sixth Annual Convention. 454, Dec.
Reports:
Committee on the Advisability of Water Departments Regulating Water Piping and Fixtures within Buildings. (Progress Report). 259, Sept. 476, Dec.
Editor. 473, Dec.
Finance Committee. 475, Dec.
Secretary. 466, Dec.
Treasurer. 469, Dec.
New York, Additional Water Supply for the City of. By WALTER E. SPEAR. 227, June.
New York State, Public Health Aspect of the Flood of March, 1936 in. By ANSELMO F. DAPPERT. 69, Mar.
Northborough, Mass., and its Improvement, Water Supply for. By ROBERT SPURR WESTON. 248, Sept.

Obituary.
John Carroll Chase. 480, Dec.
Harrison Prescott Eddy. 482, Dec.
Ohio Flood of 1936, The. By F. H. WARING. 103, Mar.
Operating Experience with Anthracite Filters. By H. S. R. MCCURDY. 37, Mar.

Operating Experiences at the Salem and Beverly Filtration Plant. By ROBERT P. JOHNSON. 185, June.
Operating Experiences with Iron Coagulants, Some. By MALCOLM PIRNIE. 437, Dec.
Operators of Water Treatment Plants, Qualifications of. By WARREN J. SCOTT. 403, Dec.
Our Introduction to Transite Pipe. By HAROLD L. BRIGHAM. 285, Sept.
Oxygen in Accelerating of the Corrosive Action of Water, The Influence of Dissolved. By F. WELLINGTON GILCREAS. 380, Dec.

Pennsylvania, Public Health Aspects of the Flood of March, 1936 in. By W. L. STEVENSON. 80, Mar.
Pipe, Experience with Transite. By A. B. RICH. 289, Sept.
Pipe in Great Britain, Development and Use of Spun Bituminous Coating for Water. By J. MITCHELL. 390, Dec.
Pipe in the United States, Development and Use of Spun Bituminous Coatings for Water. By GEORGE E. BOYD. 393, Dec.
Pipe, Our Introduction to Transite. By HAROLD L. BRIGHAM. 285, Sept.
Pipe River Crossing at Scituate, Mass., Transite. By FRANK A. MARSTON. 299, Sept.
Pipe, Transite. By GERALD W. BLAKELEY. 317, Sept.
Pipe, Underwriters Tests of Transite. By CHARLES W. SHERMAN. 282, Sept.
Pipes, Electric Grounding on Water. By J. O. K. COLEMAN. 277, Sept.
Piping and Fixtures within Buildings, Advisability of Water Departments Regulating Water. PROGRESS REPORT OF COMMITTEE. 259, Sept. 476, Dec.
Plumbing Fixtures Subject to Back-Siphonage. By LESLIE K. SHERMAN. 266, Sept.
Plumbing Systems in Relation to Cross-Connections, What Interest has a Water Purveyor in Interior. By M. W. COWLES. 261, Sept.
Public Health Aspects of the Flood of March, 1936:
New York State. By ANSELMO F. DAPPERT. 69, Mar.
Pennsylvania. By W. L. STEVENSON. 80, Mar.
Massachusetts. By ARTHUR D. WESTON. 90, Mar.

Qualifications of Operators of Water Treatment Plants. By WARREN J. SCOTT. 403, Dec.

Recreation Facilities near Public Water Supplies, Meeting the Demand for. By DAVID E. MOULTON. 370, Dec.
Regulating Water Piping and Fixtures within Buildings, Advisability of Water Departments. PROGRESS REPORT OF COMMITTEE. 259, Sept. 476, Dec.
Rigid versus Flexible Service Connections. By ARTHUR C. KING. 111, Mar.
River Crossing at Scituate Mass., Transite Pipe. By FRANK A. MARSTON. 299, Sept.

Salem and Beverly Filtration Plant, Operating Experiences at the. By ROBERT P. JOHNSON. 185, June.
Sand-Filtration Plant at Greenfield, Mass., Construction of a Modified Slow. By H. L. FIELD. 173, June.
Scituate, Mass., Transite Pipe River Crossing. By FRANK A. MARSTON. 299, Sept.
Screens, Transite for Wells and. By WM. J. LUMBERT. 310, Sept.
Seepage Through Dams. By ARTHUR CASAGRANDE. 131, June.
Service Connections, Rigid versus Flexible. By ARTHUR C. KING. 111, Mar.
Service in High Buildings, Tanks for Water. By H. E. HALPIN. 273, Sept.
Services, Factors to be Considered in Determining the Size of Mains and. By SAMUEL H. MACKENZIE. 108, Mar.
Services, Size of Meters for. By SAMUEL H. MACKENZIE. 367, Dec.
Services, Sizes of Meters for. By ROGER W. ESTY. 245, Sept.

Silvicultural Aids in the Control of Gypsy Moth in Watershed Forests. By A. C. CLINE. 235, Sept.
Siphonage, Plumbing Fixtures Subject to Back-. By LESLIE K. SHERMAN. 266, Sept.
Size of Mains and Services, Factors to be Considered in Determining the. By SAMUEL H. MACKENZIE. 108, Mar.
Size of Meters for Services. By SAMUEL H. MACKENZIE. 367, Dec.
Sizes of Meters for Services. By ROGER W. ESTY. 245, Sept.
Slow Sand-Filtration Plant at Greenfield, Mass., Construction of a Modified. By H. L. FIELD. 173, June.
Some Flood-Producing Storms of the Atlantic Seaboard. By MONTROSE W. HAYES and HORACE R. BYERS. 207, June.
Some Operating Experiences with Iron Coagulants. By MALCOLM PIRNIE. 437, Dec.
Special Equipment Cross-Connections,. By ARTHUR V. HARRINGTON. 270, Sept.
Spun Bituminous Coating for Water Pipes in Great Britain, Development and Use of. By J. MITCHELL. 390, Dec.
Spun Bituminous Coatings for Water Pipe in the United States, Development and Use of. By GEORGE E. BOYD. 393, Dec.
Storms of the Atlantic Seaboard, Some Flood-Producing. By MONTROSE W. HAYES and HORACE R. BYERS. 207, June.
Supply for Northborough, Mass., and its Improvement, Water. By ROBERT SPURR WESTON. 248, Sept.
Supply for the City of New York, Additional Water. By WALTER E. SPEAR. 227, June.
Supply for Woburn, Mass., Additional Ground Water. By JOHN P. WENTWORTH. 430, Dec.
Supply of the City of Dayton, Ohio, Development of the Ground Water. By W. W. MOREHOUSE. 219, June.
Swimming Pools, An Investigation of the Katadyn Treatment of Water with Particular Reference to. By ROBERT SHAPIRO and FRANK E. HALE. 113, Mar.

Tanks for Water Service in High Buildings. By H. E. HALPIN. 273, Sept.
Transite for Wells and Screens. By WM. J. LUMBERT. 310, Sept.
Transite Pipe. By GERALD W. BLAKELEY. 317, Sept.
Transite Pipe, Experience with. By A. B. RICH. 289, Sept.
Transite Pipe, Our Introduction to. By HAROLD L. BRIGHAM. 285, Sept.
Transite Pipe River Crossing at Scituate, Mass. By FRANK A. MARSTON. 299, Sept.
Transite Pipe, Underwriters Tests of. By CHARLES W. SHERMAN. 282, Sept.
Treatment of Water with Particular Reference to Swimming Pools, An Investigation of the Katadyn. By ROBERT SHAPIRO and FRANK E. HALE. 113, Mar.
Treatment Plants, Qualification of Operators of Water. By WARREN J. SCOTT. 403, Dec.

Underwriters Tests of Transite Pipe. By CHARLES W. SHERMAN. 282, Sept.

Water Chlorination Experience. By FREDERICK O. A. ALMQUIST. 41, Mar.
Water Departments Regulating Water Piping and Fixtures within Buildings, Advisability of. PROGRESS REPORT OF COMMITTEE. 259, Sept. 476, Dec.
Water Mains, Experiences with Chlorinating New. By GEORGE O. ADAMS and FRANCIS H. KINGSBURY. 60, Mar.
Water Pipes, Electric Grounding on. By J. O. K. COLEMAN. 277, Sept.
Water Service in High Buildings, Tanks for. By H. E. HALPIN. 273, Sept.
Watershed Forests, Silvicultural Aids in the Control of Gypsy Moth in. By A. C. CLINE. 235, Sept.
Water Supply for the City of New York, Additional. By WALTER E. SPEAR. 227, June.

Water Supply for Woburn, Mass., Additional Ground. By JOHN P. WENTWORTH. 430, Dec.

Water Supply of Northborough, Mass., and its Improvement. By ROBERT SPURR WESTON. 248, Sept.

Water Supply of the City of Dayton, Ohio, Development of the Ground. By W. W. MOREHOUSE. 219, June.

Water Treatment Plants, Qualifications of Operators of. By WARREN J. SCOTT. 403, Dec.

Well, The Needham Gravel-packed. By BAYARD F. SNOW. 409, Dec.

Wells and Screens, Transite for. By WM. J. LUMBERT. 310, Sept.

Wells, Experiences with Low-velocity Gravel-packed. By PAUL F. HOWARD. 424, Dec.

What Interest has a Water Purveyor in Interior Plumbing Systems in Relation to Cross-Connections. By M. W. COWLES. 261, Sept.

Woburn, Mass., Additional Ground Water Supply for. By JOHN P. WENTWORTH. 430, Dec.

INDEX OF ADVERTISERS.

	Page
Atlas Mineral Products Co.	xxv
Bailey, Howard E.	iii
Barbour, Frank A.	ii
Barrows, H. K.	ii
Bingham & Taylor	iv
Brainard, F. S. & Co.	xxv
Caldwell, Geo. A., Co.	xiii
Cement Lined Pipe Co.	xxv
Crosby, Irving B.	iii
Darling Valve & Mfg. Co.	ix
Donaldson Iron Co.	xxiv
Dresser, S. R., Mfg. Co.	Following front cover
Eddy Valve Co.	xv
Edson Corp., The	xxii
Ellsworth, Samuel M.	ii
Everett, Chester M.	ii
Fairbanks-Morse Co.	xxiv
Fay, Spofford & Thorndike	ii
Ford Meter Box Co.	xvii
Goodnough, X. Henry, Inc.	ii
Hayes Pump and Machinery Co.	xvii
Hays Mfg. Co.	xviii
Hersey Mfg. Co.	v
Hotel Pennsylvania	Following front cover
Hydraulic Development Corp.	x
Industrial Chemical Sales Division—West Virginia Pulp and Paper Co.	xix
Jenkins Bros.	xxxiii
Johns-Manville	xi
Kennedy Valve Mfg. Co.	xiv
Layne-Bowler New England Co.	iii
Leadite Co.	Back cover
Lock Joint Pipe Co.	Facing front cover
Ludlow Valve Mfg. Co.	xvii
Metcalf & Eddy	ii
Mueller Co.	xxxi
National-Boston Lead Co.	xvi
National Meter Co.	xii
National Water Main Cleaning Co.	viii
Neptune Meter Co.	vi
New England Water Works Association	viii
Pirnie, Malcolm	ii
Pierce-Perry Co.	xxv
Pitometer Company	ii
Pittsburgh Equitable Meter Co.	vii
Red Hed Mfg. Co.	xxxii
Rensselaer Valve Co.	xxiii
Reppucci, C. & Sons, Inc.	iii
Ross, Anthony & Son, Inc.	iii
Ross Valve Mfg. Co.	viii
Smith, The A. P., Mfg. Co.	xvii
Thorpe, Lewis D.	ii
Tredennick, J. H., Inc.	xxv
Turbine Equipment Co.	xx
U. S. Pipe and Foundry Co.	Facing back cover
Wailes Dove-Hermiston Corp.	xxiii
Wallace & Tiernan	xxi
Warren Foundry and Pipe Corp.	xxii
Weston & Sampson	iii
Whitman & Howard	iii
Wood, R. D., Co.	xxvi

(Classified index on page xxvii)

ENGINEERS

FRANK A. BARBOUR

Consulting Engineer

Water Supply, Water Purification, Sewer and Sewage Disposal, Valuations.

Tremont Building, Boston, Mass.

H. K. BARROWS

M. Am. Soc. C. E.

Consulting Hydraulic Engineer

Water Power, Water Supply, Sewerage, Drainage, Investigations, Reports, Valuations, Designs, Supervision of Construction

BOSTON, MASS. 6 BEACON ST.

Samuel M. Ellsworth

Mem. Am. Soc. C. E.

Consulting Engineer

Water Supply and Sewerage

Investigations, Reports and Designs
Supervision of Construction and Operation

12 Pearl Street, Boston

FAY, SPOFFORD & THORNDIKE

ENGINEERS

Frederic H. Fay — Charles M. Spofford
John Ayer — Bion A. Bowman
Carroll A. Farwell — Ralph W. Horne

Water Supply — Sewerage — Drainage
Structural and Foundation Problems

Investigations Reports Designs Valuations
Engineering Supervision

11 BEACON STREET BOSTON

THE PITOMETER COMPANY

ENGINEERS

Water Waste Surveys
Trunk Main Surveys
Water Distribution Studies
Penstock Gaugings

50 Church Street New York City

CHESTER M. EVERETT

Sucessor to
FULLER & EVERETT HAZEN & EVERETT

Consulting Hydraulic and Sanitary Engineer

Water Supply, Sewerage, Drainage, Valuations, Superivsion of Construction and Operation

22 East 40th Street New York City

X. HENRY GOODNOUGH, Inc.

Engineers

BAYARD F. SNOW

Water Supply, Drainage, Sewerage, Sewage Disposal, River Improvement, Disposal of Municipal and Industrial Wastes.

14 BEACON STREET, BOSTON, MASS.

METCALF & EDDY

ENGINEERS

Charles W. Sherman — John P. Wentworth
Almon L. Fales — Harrison P. Eddy, Jr.
Frank A. Marston — Arthur L. Shaw
E. Sherman Chase

Water, Sewage, Drainage, Garbage and Industrial Wastes Problems
Laboratories Valuations

BOSTON, MASS. Statler Building — HARRISBURG, PA. Telegraph Building

MALCOLM PIRNIE

ENGINEER

Water Supply, Treatment, Sewerage
Reports, Plans, Estimates,
Supervision and Operation,
Valuation and Rates.

25 West 43rd Street New York, N.Y.

LEWIS D. THORPE

Civil and Sanitary Engineer

Water Works, Sewerage and Sewage Disposal
Supervision of Construction and Operation

6 Beacon Street
BOSTON, MASS.

ENGINEERS

WESTON & SAMPSON
Consulting Engineers
Robert Spurr Weston George A. Sampson
Water Supply and Sewerage
Chemical and Bacteriological Laboratory
14 BEACON ST. - BOSTON, MASS.

WHITMAN & HOWARD
HARRY W. CLARK, Associate
Civil Engineers
(Est. 1869. Inc. 1924.)
Investigations, Designs, Estimates, Reports and Supervision, Valuations, etc., in all Water Works and Sewerage Problems.
89 Broad Street Boston, Mass.

IRVING B. CROSBY
Consulting Engineering Geologist
Investigations of Dam & Reservoir Sites and Groundwater Supplies
6 BEACON ST., BOSTON, MASS.

HOWARD E. BAILEY
Consulting Sanitary Engineer
Water Works Water Purification
Sewerage Sewage Treatment
Industrial Wastes Disposal
177 State Street, Boston, Mass.

WATER WORKS CONTRACTORS

The selection of a competent contractor is one of the best assurances of permanent satisfaction with your Water System and lasting value in your construction investment.

No Water Works Job Too Large . None Too Small

C. REPPUCCI & SONS, INC.
WATER WORKS CONTRACTORS
10 Garden Court Street (Tel. Lafayette 7330) Boston, Mass.

ANTHONY ROSS & SON, Inc.
Public Works Contractors
(Since 1890)
Water Works, Sewerage and Sewage Disposal
Office and Yard
173 Bedford Street - Lexington, Mass.
Tel. Lex. 1032

Layne-Bowler New England Company, Inc.
Developers of High Capacity Patented Gravel Wall Wells
P. D. BOWLER, Pres.
Statler Building Boston Telephone Liberty 5795

WATER WORKS CONTRACTORS AND SUPPLY HOUSES
Your card may be inserted in this space for $12 per year

TO MEMBERS:

The Association is anxious to obtain back issues of the Journal. Members who have some to dispose of are kindly requested to leave them in Room 613, Statler Building.

BINGHAM & TAYLOR'S Sliding Type Service and Valve Boxes are meeting with the approval of many New England Waterworks officials.

The cuts shown are our two and three piece sliding type adjustable valve boxes.

The flange on the bottom of the top section can be located any distance from the top.

We carry a complete stock on hand at all times.

Wire, phone write us when you are in a hurry for a shipment.

ESTABLISHED 1849

B AND T

Bingham and Taylor Corporation

MANUFACTURERS

575-601 Howard Street . . Buffalo, N. Y.

Experienced Water Works men invariably point to the

HERSEY WATER METER

as the outstanding example of water meter efficiency

HERSEY MANUFACTURING COMPANY

SOUTH BOSTON, MASS.

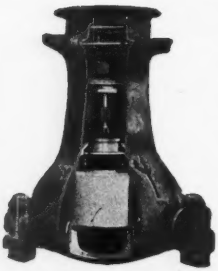
Branch Offices: New York—Portland, Ore.—Philadelphia—Atlanta—Dallas—Chicago
San Francisco—Los Angeles

NO DETERIORATION

NO OBSOLESCENCE

CAPITAL VALUE UNIMPAIRED

THE SYMBOL OF SUSTAINED ACCURACY



This Neptune Meter Casing (cut away) is 38 years old. The parts are modern. Both Frost-Proof and Split-Case types are protected by Interchangeable Parts.

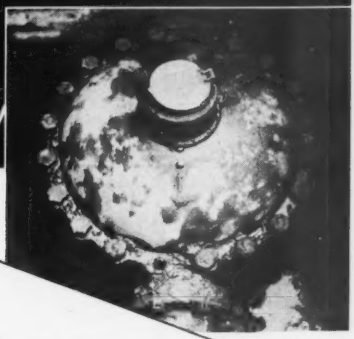
THE life and the service of Trident and Lambert Water Meters are protected by the fact that NEW Interchangeable Parts make OLD Trident and Lamberts NEW. Yet this is only one advantage of these Quality meters. A type for every service. Over 6 million made and sold the world over. Neptune Meter Company (Thomson Meter Corp.), 50 West 50th Street, (Rockefeller Center), New York City. Neptune Meters, Ltd., 345 Sorauren Avenue, Toronto, Ontario, Canada.

TRIDENT

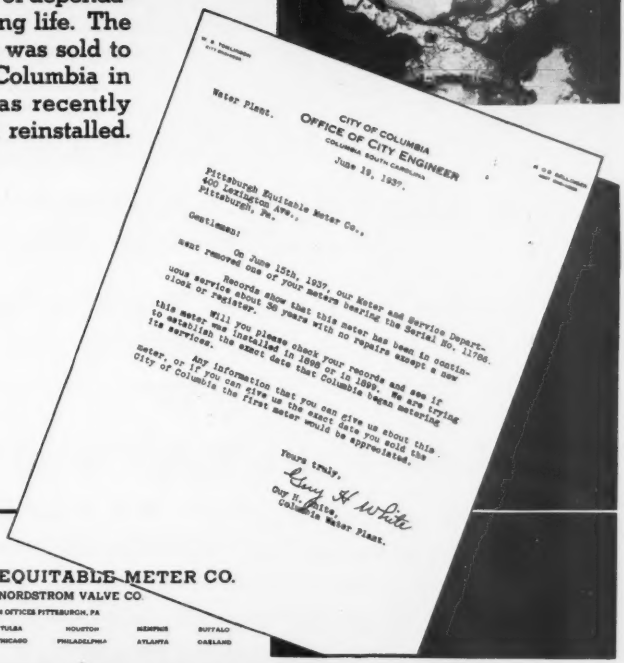
AND LAMBERT WATER METERS

IN SERVICE 39 YEARS

and still going strong!



Here's proof of dependability and long life. The above meter was sold to the City of Columbia in 1898. It was recently cleaned and reinstalled.



CITY OF COLUMBIA
OFFICE OF CITY ENGINEER
COLUMBIA, SOUTH CAROLINA

June 18, 1937.

Pittsburgh Equitable Meter Co.,
400 Lexington ave.,
Pittsburgh, Pa.

Gentlemen:

On June 15th, 1937, our Water and Service Department removed one of your meters bearing the Serial No. 11786.

Records show that this meter has been in continuous service about 38 years with no repairs except a new glass or register.

Will you please check your records and see if this meter was installed in 1898 or in 1899. We are trying to establish the exact date that Columbia began metering its services.

Any information that you can give us about this meter, or if you can give us the exact date you sold the City of Columbia the first meter would be appreciated.

Yours truly,

Guy H. White

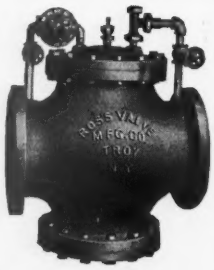
Guy H. White,
Columbia Water Plant.

Water Plant.

PITTSBURGH EQUITABLE METER CO.
MERCO NORDSTROM VALVE CO.
MAIN OFFICES PITTSBURGH, PA

NEW YORK · LOS ANGELES · TULSA · HOUSTON · MEMPHIS · BUFFALO
COLUMBIA · KANSAS CITY · CHICAGO · PHILADELPHIA · ATLANTA · OAKLAND

PITTSBURGH WATER METERS



THE STANDARD FOR OVER 50 YEARS

Automatic Pressure Control Valves
Water Works Specialties

Altitude — Pressure Reducing — Surge Relief and Combination Valves
Portable Fire Hydrants
Hydraulic Booster Pumps

ROSS VALVE MFG. CO., INC. TROY, N.Y.

Health and Protection First

Water delivered through dirty pipes may be a MENACE.

Incrusted water pipes mean inefficiency and loss of Fire Protection.

We Guarantee the Results of Our Method of Cleaning.

WRITE US.

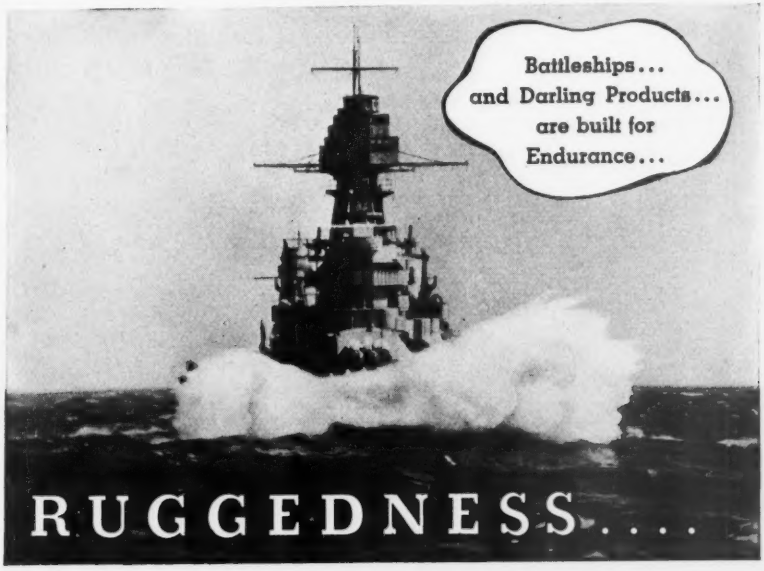
National Water Main Cleaning Co.

50 Church Street New York City

THE NEW ENGLAND WATER WORKS ASSOCIATION
is very desirous of obtaining
the following early issues of the Journal:

Vol. 2. Nos. 1, 2, 3.	Vol. 8, No. 1.
Vol. 3, No. 1.	Vol. 11, No. 4.

Please communicate with the office
613 Statler Building
Boston, Mass.



YOU CAN COUNT ON DARLING VALVES and Fire Hydrants for tough jobs —because that's the kind of work they're built for. Quality workmanship and sturdy construction insure real ruggedness in Darling Products—year after year.

Incidentally, this characteristic ruggedness means economy, because maintenance and repair costs are lowered.

The nearest Darling representative will be glad to talk about your particular problems. Of course, there is no obligation.

DARLING VALVE & MFG. CO.

Williamsport, Pa.

Representatives in

New York Philadelphia Oklahoma City
Houston Pittsburgh Toledo
Evanston, Ill.

DARLING
GATE VALVES *and*
FIRE HYDRANTS

Six important features have won nationwide approval for Darling Hydrants.

The steadily increasing use of Darling Valves proves that performance outweighs promises.

"Never a Failure in Over 22 Years!"

WE like to talk about saving in material and labor—the strong, tight, flexible joints made with Hydro-Tite—the thousands of miles of pipe jointed with it.

More important, perhaps, is the fact that with hundreds of users—each laying pipe under different conditions—not a single one has reported a Hydro-Tite failure.

We make it very easy for you to change over to Hydro-Tite. Our Data Book outlines a novel proposition. Write for it.

A Symbol of Quality

A Dependable Self-Caulking Joint Compound

HYDRO-TITE

HYDRAULIC DEVELOPMENT CORPORATION

Main Sales Office: 50 Church Street, New York, N. Y.
General Offices and Works: West Medford Station, Boston, Mass.

Here's the INSIDE STORY on Low Pumping Costs!

Constant C-140 is responsible for Permanent Savings on this Non-Tuberculating Pipe . .

ISN'T THIS TRUE? Since water pipe is laid solely for the purpose of carrying water, in the last analysis your investment is not in pipe but in water transportation facilities.

Why, then, in figuring the cost of a new main, should the yardstick be cost per foot of pipe? Isn't it much more logical to evaluate a water main primarily on its effectiveness as a water carrier?

And not solely on its effectiveness when new . . . all too often water mains are at the mercy of tuberculation, which constantly decreases the delivery capacity of ordinary pipe.

Hence, can you afford to pass up the savings in pumping costs offered by Transite Pipe, as already proved by hundreds of installations?

C-140 is the conservative minimum coefficient of Transite . . . not merely when first laid . . . not merely after five years or ten . . . but indefinitely.

1500' OF TRANSITE PIPE from a city main into an industrial plant were tested by The Pitometer Co., N. Y. C. Conclusion —"From a study of the data, we believe that an average coefficient of C-145 is very nearly correct for this pipe."

Made of asbestos and cement . . . and hence non-metallic . . . Transite Pipe cannot tuberculate. From the day it comes off the polished steel mandrel that forms its smooth interior wall, this pipe's all-important value of C stays unchanged. And thus pumping costs remain permanently low.

Send for a copy of our brochure, containing the complete story of Transite's important installation and maintenance savings as well as low pumping costs. Write to Johns-Manville, 22 East 40th Street, New York City.

Johns-Manville

TRANSITE PRESSURE PIPE

An Asbestos Product

...and frozen water meters

But the far-sighted and thrifty water commissioners who are purchasing L. H. Nash Water Meters now will save thousands of dollars this winter in the cost of replacing broken bases and cracked casings.

For the exclusive frost feature of the L. H. Nash confines damage by freezing to the breakage of a few cast-iron frost washers, which can easily be replaced, at a cost as low as six cents a meter.

L. H. Nash Meter
Frost Model

NATIONAL Meter COMPANY

4207 FIRST AVENUE
BROOKLYN, N. Y.

BOSTON · CHICAGO · DALLAS
LOS ANGELES · SAN FRANCISCO

SERVICE & QUALITY

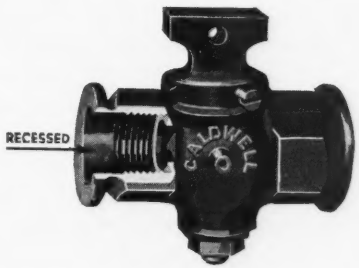
The growth of any business rests chiefly on two factors—SERVICE to its customers—QUALITY of its merchandise.

No two factors of merchandising are more important to us than SERVICE and QUALITY. They are paramount. 90% of our stocked-items orders are shipped the same day as received. All merchandise is of highest quality procurable for our selling prices.

1937 is almost history. It closes our most successful year of catering to the WATER WORKS trade.—We are grateful.—We prepare for 1938.

Hundreds of items of BRASS goods, CURB and VALVE Boxes, Tools, Repair Equipment, Instruments, etc., always in stock. We illustrate but one item, which is typical of the CALDWELL LINE.

EXTRA HEAVY & RECESSED



NEWPORT CURB COCKS

Recessing entirely covers service pipe threads, adds strength at normally weakest point, retards corrosive action.

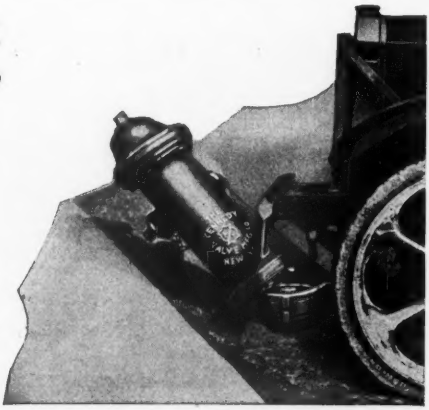
SERVICE in shipments *SERVICE in merchandise*

GEORGE A. CALDWELL CO.

BOSTON MATTAPAN SQUARE MASS.

When a truck runs "amuck"

and crashes into a Kennedy SAFETOP Fire Hydrant



Send for Bulletins

IN NO INSTANCE—either on demonstration test or in accidental collisions, has the Safety Breakable Section ever failed in its function of preventing breakage of the major and expensive parts of the SAFETOP. The only parts that need be replaced after breakage are a threaded standpipe ring and a stem coupling. These parts cost $6.00—a very small fraction of the cost of the complete hydrant which must ordinarily be replaced after breakage from accidental collision. Repairs do not necessitate shutting off the water pressure, and can be completed within half an hour.

In addition to its unique safety feature, the Kennedy SAFETOP Fire Hydrant assures quick response with full main pressure delivered at the nozzle in fire service; and its simple operating mechanism and wear-resisting valve facings last indefinitely. Write for bulletins describing its many special features.

The Kennedy Valve Mfg. Co., Elmira, N.Y.

KENNEDY

SAFETOP FIRE HYDRANT

REG. U.S. PAT. OFF.

EDDY

Valves and Hydrants

Distinctive Features of the EDDY Valves

ONLY three parts are moved by the Stem—the ball and the two gates. Each gate is hung from one of the trunnions on the ball. A convex surface at the base of each trunnion fits a concave surface on the back of the gate. This allows the gates to adjust themselves properly to their seats. . . . The gates, being free to revolve on the trunnions, do not always seat in the same position. Gates are center bearing and adjustable. They are forced to their seats with equal pressure at all points. There are two hooks on the ball on sizes 4-inch and larger, which loosely engage with the gates.

Distinctive Features of Our New Swivel Top Hydrants

THIS new hydrant has all the advantages of the popular EDDY fire hydrant, plus several additional features. . . . Nozzles are in a short flanged section of the standpipe, which may be unbolted and turned to different positions. . . . Should the standpipe be broken, only the casting below the swivel head need be replaced. . . . To raise the hydrant to conform to a new grading, simply insert a flanged extension piece below the swivelhead. No digging. To add a steamer nozzle at any time, it is only necessary to replace the swivel head with one having a steamer nozzle.

Besides valves and hydrants to meet the most exacting demands of waterworks service, the complete EDDY Line includes: valves for sewage disposal works; valves for steam, gas and oil; check valves, foot valves, plug valves, shear gates, indicator posts, etc. EDDY valves are made in three classes: Iron Body Bronze Mounted, All Bronze, and All Iron Valves.

Eddy Valve Co.

WATERFORD NEW YORK

LEAD PIPE

Used by leading **WATER WORKS** for over 50 years. If proper weight is used, combined with good workmanship, your **FINAL COST** is assured, as **REPAIRS** are unnecessary. **LEAD PIPE** is sufficiently ductile to conform to any sagging condition. There is no **RUSTING** of pipe or joints; no **DISCOLORATION** of water.

LEAD WOOL

Every Atom Pure Lead

For calking pipe joints under the most difficult conditions; for overhead joints or in wet places where the use of molten lead is not only impracticable but dangerous — **LEAD WOOL** may be used to advantage.

It makes an absolutely tight joint which will withstand the highest pressure, yet be sufficiently elastic to allow considerable sagging or settling of the pipe, without danger of leaks.

Compared with the poured joint, in this respect, the superiority of **LEAD WOOL** is apparent.

LEAD PIPE TIN-LINED LEAD PIPE
PURE BLOCK TIN PIPE SOLDER
DUTCH BOY WHITE LEAD & RED LEAD

Highest Quality Soft Virgin Omaha Pig Lead

NATIONAL-BOSTON LEAD CO.

800 Albany St. Boston, Mass.

Specify **LUDLOW**

Sewerage and Filtration Equipment....

Specify Ludlow gates and valves for trouble-free performance. They are available in all types and sizes — and conform to A. W. W. Association standards. Write for information and quotations.

The LUDLOW VALVE MFG. CO.
TROY, NEW YORK

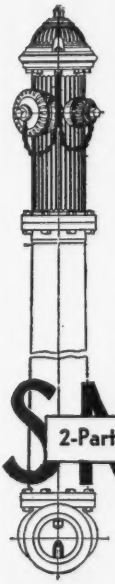
PUMPS — CENTRIFUGAL, STEAM, TRIPLEX, ROTARY

POWER — DIESEL, GASOLINE, STEAM, ELECTRIC

PARDEE CHLORINATORS — DIRECT SOLUTION, VACUUM

PORTABLE — LABOUR SELF-PRIMING PUMP, AIR COMPRESSORS AND TOOLS
For Rent or Sale

HAYES PUMP & MACHINERY CO.
125 Purchase Street Boston, Mass.
Hancock 7957-7958



Minimum Trouble and Expense When Breaks Come

THE Smith Two-Part Standpipe Hydrant was designed to make the expense as small as possible when there is a break as the result, for instance, of careless auto truck driving.

The upper section will always break first. It can easily be renewed. And of course there can be no leakage of water because the main valve is of the compression type.

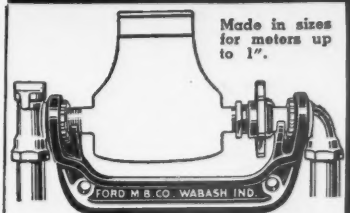
SMITH
2-Part Standpipe Hydrant

THE A. P. SMITH MFG. COMPANY
EAST ORANGE, N. J.

FORD YOKES

FOR RISER SETTINGS . . FOR ANGLE SETTINGS . . FOR LINE SETTING

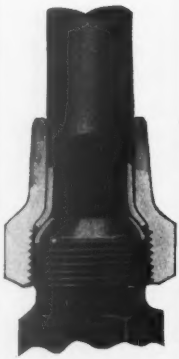
MAKE EASY METER CHANGES



Made in sizes for meters up to 1".

Ford Yokes connect inlet and outlet service pipes permanently and make easy, trouble-free meter changes. May include a... inverted ground-key angle valve at the meter inlet. Made for all types of piping connections. Hundreds of thousands in service. Further information for the asking.

The Ford Meter Box Co.
WABASH, INDIANA



HAYS begins at the MAIN

Since 1869 Hays has built to the exacting requirements of the Water Works Industry. Tap the Main with a Hays Tapping Machine and follow through with dependable Hays Service Fittings for iron pipe, lead or copper. Hays Corporation Stops and Curb Stops are made in all styles and sizes. Write for Catalog.

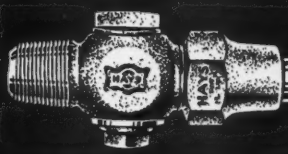
HAYS RADIUS SEAL JOINT

This type of joint was designed to meet the specific requirements of certain Water Departments and is available directly on all styles of Hays Copper Service fittings.

HAYS DOUBLE SEAL JOINT

This joint features a 2-faced pipe flare (45° + 90°) and a 2-faced machined seal (45° + 90°) which is by test the strongest flanged connection available. Available by Adapter on any Corporation Stop and directly on more than 400 styles and sizes of Hays Service and Plumbing fittings.

USE THE HAYS COPPER SERVICE METHOD



Hays Adapts Copper to meet any Requirements

As a pioneer in the development of copper pipe services, Hays has popularized its use by making it easily adaptable to meet existing line equipment economically. Every community can have the advantage that copper pipe makes possible from Main to Curb to House with the Hays Copper Service Method. Let us have your problem.

HAYS MFG. CO.

ERIE, PA.

HAYS

PLUMBING BRASS
BATH FIXTURES
COPPER PLUMBING
GAS SERVICE GOODS
WATER SERVICE GOODS
IRON PRODUCTS
TAPPING MACHINES

PREPARATION . . .

THE public seldom realizes the preparation required in producing water suitable for household needs. Careful as the personnel may be in preparing water free from bacteria and suspended matter, nevertheless, if tastes and odors are present in the tap, Mr. John Public in the smaller communities will usually resort to water from unauthorized sources, in the belief that the sparkling glass of well, or spring water, represents the "tops". Case history is replete with serious epidemics resulting from the use of unauthorized sources of water.

In the larger communities, when tastes and odors break through, Mr. and Mrs. John Public and their neighbors rise in protest and flood the Water Department with complaints, abuses, etc. The local press, with their headlines, play this situation up as important news and frequently it either results in the dismissal or the non-appointment of personnel who have well served their Municipality.

Why not follow the lead of many Municipalities in feeding ACTIVATED CARBON daily so that when serious tastes and odors are present in the raw water supply, the plant has already been seeded with ACTIVATED CARBON and all that is necessary is to step up the dose in order to furnish a palatable water free from complaint.

Our Service Men are prepared to run Threshold Tests in your Plant, to show where the application of ACTIVATED CARBON will give you the most economical use.

POWDERED ACTIVATED NUCHAR CARBON

We have released to over 1,000 newspapers a résumé of the treatment water is given to make it fit for household use with the idea of building up Good-Will for the water personnel. Mimeographed copies are available to water men in the event they wish to use it with their local newspapers.

INDUSTRIAL CHEMICAL SALES

DIVISION WEST VIRGINIA PULP AND PAPER COMPANY

230 Park Avenue
New York, N. Y.

417 Schofield Building
Cleveland, Ohio

205 West Wacker Drive
Chicago, Illinois

DE LAVAL

Pumps selected by the

Metropolitan District Commission

for latest pumping station

Two 125 H.P. motor-driven centrifugal pumps in the new Belmont, Mass., pumping station of the Metropolitan District Commission

Each pump is designed to handle 3 million gallons of water per day against a total dynamic head of 162 feet.

The complete switchboard shown in the photograph is of the Dead Front type. We furnished pumping equipment and switchboard all erected and wiring between switchboard and motors.

TURBINE EQUIPMENT COMPANY

OF NEW ENGLAND

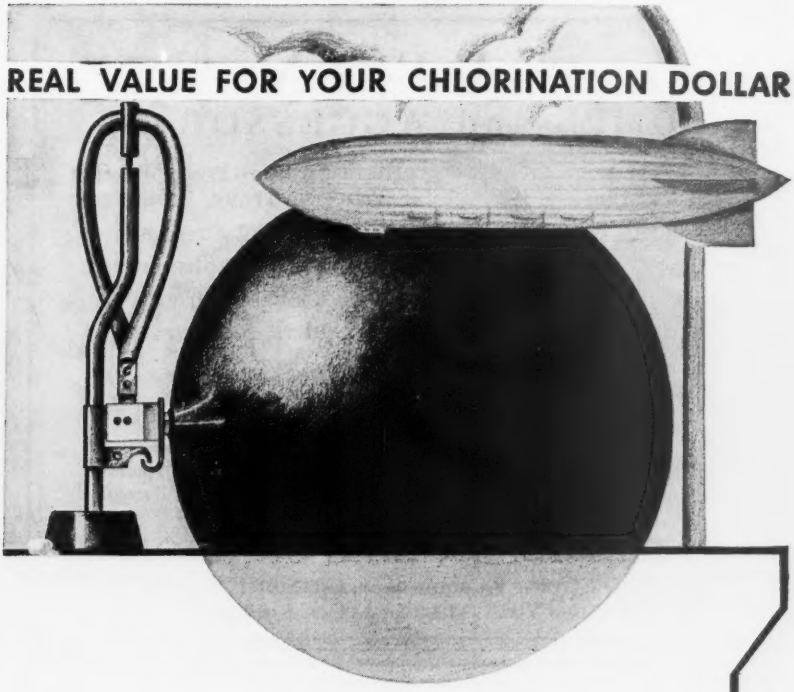
80 Federal Street **Phone LIB erty 5993-5994** **Boston, Mass.**

New England Representative for

DE LAVAL STEAM TURBINE COMPANY

TRENTON, N. J.

REAL VALUE FOR YOUR CHLORINATION DOLLAR



Chlorination requires FLOATING POWER, TOO

POWER that floats on the water inside a bell jar controls the operation of a W&T Visible Vacuum Chlorinator No hidden diaphragms, no springs—only a needle valve operated by a floating hard rubber ball regulates the inflow of chlorine maintaining an even, constant pressure whether the equipment is feeding at its maximum or minimum. And not only a constant regulation, but a constant protection against escape of gas should the operating water supply fail. Immediately, the floating ball drops, seating the needle valve, and the gas is cut off until the trouble may be investigated and operation resumed.

Such carefully thought out design, coupled with meticulous attention to every small detail of material selection and manufacturing, accounts for the recognized accuracy, dependability and long life of W&T equipment. When specifying or purchasing equipment for the important job of Chlorination, be sure you call for W&T — for over twenty years the accepted standard of Real Value in the Chlorinator field.

Ask for Technical Publications 38, 157 and 158.

"The Only Safe Water is a Sterilized Water"

WALLACE & TIERNAN CO. INC.

Manufacturers of Chlorine and Ammonia Control Apparatus

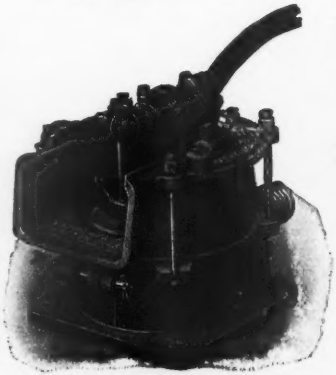
NEWARK, N. J

Branches in Principal Cities

CHLORINATORS FOR WATER WORKS • SEWAGE PLANTS • SWIMMING POOLS • INDUSTRIAL PLANTS

SA-71

EDSON
PUMPS and ACCESSORIES



Hand Pumps – Power Pumps
Truck or Trailer Mounted
Edson Special Suction Hose
Red Seal Diaphragms
Edson Bronze Hydrant Pump
Strainers, Adapters, etc.

Distributors for
Pollard Pipe Line Equipment
Redi-Prime Pumps
Electric Pipe Thawers
Standard Hydrant Protector
Universal Water Leak Detector

THE EDSON CORPORATION
49 D Street, Tel. SOUth Boston 3041 South Boston
New York: 142 Ashland Place, Brooklyn

Warren Foundry & Pipe Corp.
ALSO
Warren Pipe Co. of Mass., Inc.

SALES OFFICES
11 BROADWAY, NEW YORK
75 FEDERAL STREET, BOSTON, MASS.

Manufacturers of

CAST IRON PIPE

Flanged Pipe ***Flexible Joint Pipe***
Bell and Spigot Pipe
Special Castings ***Short Body B. & S. Specials***
Warren (WF) Spun Centrifugally Cast Iron Pipe

WORKS: PHILLIPSBURG, N. J. and EVERETT, MASS.

Large Stock Enables Us to Make Prompt Shipments

Few Products In Any Field Are So Clearly Recognized for Superiority of Service As

SPUN **BITUMASTIC** LINING

REG. U.S. PAT. OFF.

The Report of the Committee on **PIPE LINE COEFFICIENTS** of the New England Water Works Association definitely proves the absolute economic necessity of lining all water pipe.

BITUMASTIC SPUN LINING is assigned a higher value of the coefficient *C* than any other lining. This insures the highest initial flow. More important —this high flow will be maintained for many years.

BITUMASTIC ENAMEL is not affected by tuberculating waters. Actual inspection of pipe in service and carrying tuberculating waters shows **BITUMASTIC** unaffected. This is real proof.

No taste, color, or odor imparted to the water.

Wailes Dove-Hermiston Corporation

General Office
17 Battery Place
New York

New England Representative
W. D. Barker, Room 606
250 Stuart St., Boston, Mass.

The "COREY" Hydrant

Why you should use GENUINE COREY HYDRANTS

Water to Nozzles quicker than other Hydrants.

Standpipe can be removed and replaced without shutting off water in main.

Ease of operation insured by knuckle joint principle.

Only 13 turns to completely open or completely close, but full flow with only 4 turns.

Nozzles screwed in — not leaded.

Can be lengthened without shutting off water.

Will not flood if broken.

Positive Drip — cannot freeze.

Standpipe can be revolved quarter turns — Nozzles always in right direction.

Ask for our Catalog "G"

CHARLES L. BROWN,
New England Sales Manager, Lock Box 2, Northboro, Mass.

RENSSELAER VALVE COMPANY
TROY, N. Y.

DONALDSON IRON CO.

MANUFACTURERS
...OF...

CAST IRON PIPE

...AND...

Special Castings for Water and Gas.
Also Flange Pipe and Fittings.

EMAUS, LEHIGH COUNTY, PA.

New York Office: E. A. NOONAN, 225 Broadway
New England Office: CHARLES F. GLAVIN, 35 Winslow Rd., Brookline, Mass.

WATER PROBLEM SOLVED BY NEEDHAM, MASS.

X. Henry Goodnough, Inc.
Engineers

● **The town of Needham can well be proud of its new water pumping station, for as city officials state, "Our water troubles will be over for a good many years to come." Believed to be the first Municipal Diesel driven Turbine Pump installation in New England, this system is equipped with a Fairbanks-Morse single-cylinder Diesel which powers an F-M Turbine Pump to economically supply the best quality water from an underground reservoir.**

Needham, as well as many other New England municipalities equipped by Fairbanks-Morse, is showing a substantial saving in operating costs. Get the facts on F-M power and pumping epuiqment by writing to Fairbanks, Morse & Co., 178 Atlantic Avenue, Boston, Mass.

FAIRBANKS-MORSE COMPANY

Power • Pumping • and • Weighing • Equipment

The

METER-MASTER

Increase Your Revenue

Cut Your Capital Investment

"Weed Out Oversized" Meters

The only rate recorder which can be attached to *any* make of meter, single or compound, without interrupting its record.

F. S. BRAINARD & CO.

formerly

BRAINARD & HATCH

246 Palm Street

Hartford, Conn.

Job Finished

Days Sooner

If you use Tegul-MINERALEAD in Bell and Spigot Main jointing, your pipe lines should meet a reasonable leakage specification at once. Trenches can be closed and streets restored to normal without delay. • Tegul-MINERALEAD is a sulphur base compound with all the advantages which have won high favor for MINERALEAD —ingot form; convenient to transport, store and handle; impervious to snow, rain and slush; composition cannot change in transit; needs no skilled labor; no caulking or deep bell holes.

A Tegul PRODUCT

For booklet, address

The ATLAS MINERAL

Products Co. of Penna.

Mertztown, Pennsylvania

Tegul-MINERALEAD

Improved Jointing Compound for Bell & Spigot Water Pipe

CEMENT LINED SERVICE PIPE

Cement lined pipe has eliminated corrosion and metal contamination for 60 years.

Write for Literature

CEMENT LINED PIPE CO.

LYNN, MASS.

PIERCE-PERRY CO.

Wholesalers of

Water Works Brass Goods.

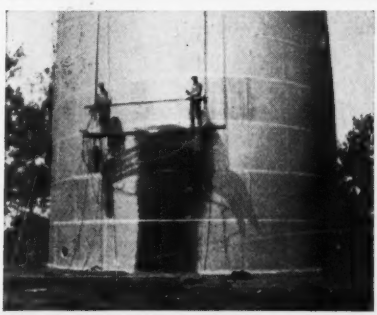
Byers Wrought Iron Pipe.

Youngstown Steel Pipe.

Valve and Service Boxes.

236 Congress St., Boston, Mass.

Telephone, Hancock 7817-7818.



STANDPIPE PAINTING

Sandblasting Power Chipping

Power Wire Brushing

PAINTING by BRUSH or SPRAY

J. H. TREDENNICK, Inc.

10 High Street Boston, Mass.

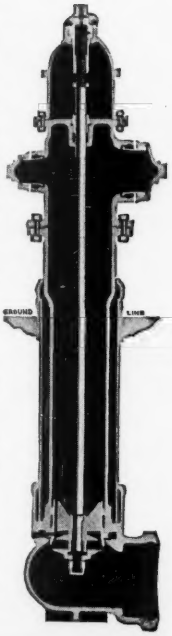
"Let it Snow. WHEN WE INSTALLED MATHEWS HYDRANTS WE BURIED OUR TROUBLES FOREVER"

Maintenance men laugh at winter — after they get Mathews Hydrants.

NO FREEZING. There's nothing that will freeze about this hydrant. Its operating threads are protected from above and below. Its barrel is emptied immediately after use by a positive and automatic drain valve. The entire hydrant is dry except when in use.

NO HEAVING. Deep frosts put a terrific strain on most hydrants. The swelling force of frozen ground pulls the hydrant away from its main, cracking castings or starting joints. But not Mathews. It is the one hydrant surrounded by a loose protection case. Frost can't heave any water-carrying part.

NO DIGGING. Plant a Mathews Hydrant, and you'll never dig it up. If a truck smashes it, you just unscrew the broken barrel and replace it from above. The same for overhauls, modernizing or grade changing. Specify Mathews. It will pay you well.



Mathews Hydrants
BUILT FOR EMERGENCIES

R. D. WOOD CO.
400 Chestnut St., Phila., Pa.

manufacturers of SAND-SPUN PIPE which is centrifugally cast in sand molds, and R. D. Wood heavy-duty gate valves for water works.

CLASSIFIED DIRECTORY OF ADVERTISEMENTS.

PAGE

ACTIVATED CARBON
Industrial Chemical Sales Division—West Virginia Pulp and Paper Co. xix

AIR COMPRESSORS.
Hayes Pump and Machinery Co. xvii

ASBESTOS CEMENT PIPE.
Johns-Manville xi

BRASS GOODS.
(See also Pipe, Brass.)
Caldwell, George A., Co. xiii
Cement Lined Pipe Co. xxv
Hays Mfg. Co. xviii
Mueller Co. xxxi
Pierce-Perry Co. xxv
Red Hed Mfg. Co. xxxii
Smith Mfg. Co., The A. P. xvii

CALKING MACHINERY AND TOOLS.
Mueller Co. xxxi
Smith Mfg. Co., The A. P. xvii

CAST IRON PIPE. (See Pipe, Cast Iron.)

CEMENT LINED PIPE. (See Pipe, Cement Lined.)

CHECK VALVES.
Darling Valve & Mfg. Co. ix
Mueller Co. xxxi

CHEMICAL FEED APPARATUS.
Wallace and Tiernan Co., Inc. xxi

CHLORINATORS.
Wallace & Tiernan Co., Inc. xxi

CLAMPS, RIVER.
Dresser, S. R., Mfg. Co. . . . . Following front cover

CLAMPS, SERVICE
Mueller Co. xxxi

CLEANING WATER MAINS.
National Water Main Cleaning Co. viii

COCKS, CURB AND CORPORATION.
Caldwell, George A., Co. xiii
Hays Mfg. Co. xviii
Mueller Co. xxxi
Pierce-Perry Co. xxv
Red Hed Mfg. Co. xxxii
Smith Mfg. Co., The A. P. xvii

CONCRETE PIPE. (See Pipe, Concrete.)

CONDENSERS.
Hayes Pump and Machinery Co xvii

CONSTRUCTION EQUIPMENT.
Edson Corp., The xxii

CONTRACTORS.
Layne-Bowler New England Co. iii
National Water Main Cleaning Co. viii
Repucci, C. & Sons, Inc. iii
Ross, Anthony & Son iii

COUPLINGS, FLEXIBLE PIPE.
Dresser, S. R., Mfg. Co. . . . . Following front cover

COUPLINGS, REPAIR
Caldwell, George A. Co. xiii

CURB BOXES.
Bingham and Taylor iv
Caldwell, George A., & Co. xiii
Hays Mfg. Co. xviii
Mueller Co. xxxi

CURB AND VALVE BOX FINDERS.
Caldwell, George A., Co. xiii

DIAPHRAGMS, PUMP.
Edson Corp., The . . . . . x ii

CLASSIFIED DIRECTORY OF ADVERTISEMENTS *(Continued)*.

ENGINEERS. Page

Bailey, Howard E. . . . iii
Barbour, Frank A. . . . ii
Barrows, H. K. . . . ii
Crosby, Irving B. . . . iii
Ellsworth, Samuel M. . . . ii
Everett, Chester M. . . . ii
Fay, Spofford & Thorndike . . . ii
Goodnough, Inc., X. Henry . . . ii
Metcalf & Eddy . . . ii
Pirnie, Malcolm . . . ii
Pitometer Co. . . . ii
Thorpe, Lewis D. . . . ii
Weston & Sampson . . . iii
Whitman & Howard . . . iii

ENGINES. (See Pumps and Pumping Engines.)

EQUIPMENT. (See Contractors' Equipment.)

ERECTORS, WATER WORKS AND POWER MACHINERY.

Hayes Pump and Machinery Co. . . . xvii
Turbine Equipment Co. . . . xx

FEED WATER HEATERS.

Hayes Pump and Machinery Co. . . . xvii
Ross Valve Mfg. Co. . . . viii

FILTER RATE CONTROLLERS AND GAGES. (See Rate Controllers.)

FILTERS AND WATER SOFTENING PLANTS.

Ross Valve Mfg. Co. . . . viii

FILTRATION PLANT EQUIPMENT.

Ross Valve Mfg. Co. . . . viii
Wallace & Tiernan Co., Inc. . . . xxi

FLEXIBLE JOINTS.

U. S. Pipe and Foundry Co. . . . Facing back cover

FLAP VALVES.

Mueller Co. . . . xxxi

FURNACES, ETC.

Atlas Mineral Products Co. . . . xxv
Leadite Co., The . . . Back cover
Mueller Co. . . . xxxi
Smith Mfg. Co., The A. P. . . . xvii

GATE VALVES. (See Valves.)

HOSE, SUCTION AND CONDUCTION.

Edson Corp., The . . . xxii

HOTELS.

Pennsylvania . . . Following front cover

HYDRANT PROTECTORS.

Edson Corp., The . . . xxii

HYDRANTS, FIRE.

Darling Valve & Mfg. Co. . . . ix
Eddy Valve Co. . . . xv
Kennedy Valve Mfg. Co. . . . xiv
Ludlow Valve Mfg. Co. . . . xvii
Mueller Co. . . . xxxi
Rensselaer Valve Co. . . . xxiii
Ross Valve Mfg. Co. . . . viii
Smith Mfg. Co., The A. P. . . . xvii
Wood, R. D., Co. . . . xxvi

HYDRANT PUMPS

Edson Corp., The . . . xxii

INSTRUMENTS. (See Water Works Instruments.)

LEAD.

National-Boston Lead Co. . . . xvi

LEAD PIPE. (See Pipe, Lead.)

LEAD WOOL.

National-Boston Lead Co. . . . xvi

LEAK FINDERS.

Pitometer Co. . . . ii
Edson Corp., The . . . xxii

CLASSIFIED DIRECTORY OF ADVERTISEMENTS (*Continued*).

METERS, WATER AND OIL. Page
Hersey Mfg. Co. . . . v
National Meter Co . . . xii
Neptune Meter Co. . . . vi
Pitometer Co. . . . ii
Pittsburgh Equitable Meter Co. . . . vii

METER COUPLINGS.
Ford Meter Box Co. . . . xvii

METERS (VENTURI TYPE).
Mueller Co. . . . xxxi
National Meter Co. . . . xii

METER BOXES.
Bingham and Taylor . . . iv
Ford Meter Box Co. . . . xvii

METER MASTER
Brainard, F. S. & Co. . . . xxv

METER TESTERS.
Ford Meter Box Co. . . . xvii
Mueller Co. . . . xxxi

OIL ENGINES, DIESEL.
Fairbanks-Morse Co. . . . xxiv
Hayes Pump and Machinery Co. . . . xvii

PAINTING
Tredennick, J. H., Inc. . . . xxv

PIPE, BRASS.
Caldwell, George A. Co. . . . xiii
Pierce-Perry Co. . . . xxv

PIPE, CAST IRON (AND FITTINGS).
Donaldson Iron Co. . . . xxiv
U. S. Cast Iron Pipe and Foundry Co. . . . Facing back cover
Warren Foundry and Pipe Corp. . . . xxii
Wood, R. D., Co. . . . xxvi

PIPE, CEMENT LINED.
Cement Lined Pipe Co. . . . xxv

PIPE, CONCRETE.
Lock Joint Pipe Co. . . . Facing front cover

PIPE CUTTING MACHINES.
Smith Mfg. Co., The A. P. . . . xvii

PIPE JOINTING MATERIAL.
Atlas Mineral Products Co. . . . xxv
Hydraulic Development Co. . . . x
Leadite Co., The . . . Back cover

PIPE, LEAD.
National-Boston Lead Co. . . . xvi

PIPE LINING.
Wailes Dove-Hermiston . . . xxiii

PIPE, TRANSITE
Johns-Manville . . . xi

PIPE, WROUGHT IRON AND STEEL.
Pierce-Perry Co. . . . xxv

PLUG VALVES.
Mueller Co. . . . xxxi

PITOMETERS.
Pitometer Co. . . . ii

PORTABLE AIR COMPRESSORS. (See Air Compressors.)

POWER WIRE BRUSH, INC.
Tredennick, J. H., Inc. . . . xxv

PRESSURE REGULATORS.
Caldwell, George A., Co. . . . xiii
Mueller Co. . . . xxxi
Ross Valve Mfg. Co. . . . viii

CLASSIFIED DIRECTORY OF ADVERTISEMENTS *(Continued)*.

PAGE

PROVERS, WATER.
Pittsburgh Equitable Meter Co. . . . vii

PUMPS AND PUMPING ENGINES.
Edson Corp., The . . . xxii
Fairbanks-Morse & Co. . . . xxiv
Hayes Pump and Machinery Co. . . . xvii
Ross Valve Mfg. Co . . . viii
Turbine Equipment Co. . . . xx
Wood, R. D., Co. . . . xxvi

RATE CONTROLLERS.

SHEAR GATES.
Mueller Co. . . . xxxi

SLEEVES, PIPE LINE REPAIR.
Dresser, S. R., Mfg. Co. . . . Following front cover

SLEEVES, RIVER.
Dresser, S. R., Mfg. Co. . . . Following front cover

SLEEVES AND VALVES, TAPPING.
Ludlow Valve Mfg. Co. . . . xvii
Mueller Co. . . . xxxi
Rensselaer Valve Co. . . . xxiii
Smith Mfg. Co., The A. P. . . . xvii

SLUICE GATES.
Mueller Co. . . . xxxi

STANDPIPES
Tredennick, J. H., Inc. . . . xxv

SUPPLIES AND TOOLS.
Caldwell, George A., Co. . . . xiii
Hays Mfg. Co. . . . xviii
Leadite Co., The . . . Back cover
Pierce-Perry Co. . . . xxv
Smith Mfg. Co., The A. P. . . . xvii

TAPPING MACHINES.
Hays Mfg. Co. . . . xviii
Mueller Co. . . . xxxi
Red Hed Mfg. Co. . . . xxxii
Smith Mfg. Co., The A. P. . . . xvii

TAPPING SLEEVES. (See Sleeves and Valves, Tapping.)

VALVE BOXES.
Bingham and Taylor . . . iv
Caldwell, George A. Co. . . . xiii
Ford Meter Box Co. . . . xvii
Mueller Co. . . . xxxi
Rensselaer Valve Co. . . . xxiii
Wood, R. D., & Co. . . . xxvi

VALVE INSERTING MACHINES.
Smith Mfg. Co., The A. P. . . . xvii

VALVE SPECIALTIES.

VALVES, GATE.
Darling Valve & Mfg. Co. . . . ix
Eddy Valve Co. . . . xv
Jenkins Bros. . . . xxxiii
Kennedy Valve Mfg. Co. . . . xiv
Mueller Co. . . . xxxi
Rensselaer Valve Co. . . . xxiii
Ross Valve Mfg. Co. . . . viii
Smith Mfg. Co., The A. P. . . . xvii
Wood, R. D., Co. . . . xxvi

VALVES, REGULATING.
Mueller Co. . . . xxxi
Ross Valve Mfg. Co. . . . viii

WATER WASTE DETECTION.
Pitometer Co. . . . ii

WATER WORKS INSTRUMENTS.
Caldwell, George A. Co. . . . xiii

WATER WORKS JOURNALS.
Journal of the New England Water Works Association . . . viii

WELL CONNECTIONS.
Red Hed Mfg. Co. . . . xxxii

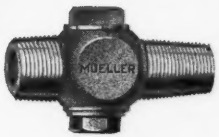
WROUGHT IRON PIPE. (See Pipe, Wrought Iron and Steel.)

MUELLER

CURB AND CORPORATION STOPS

FOR

COPPER
LEAD
IRON



All Mueller Stops are engineered strictly for their particular type of connection, being scientifically designed to give them strength where it is needed most. You will find that Mueller Stops have extra large wrench surfaces, heavy metal walls, extra long skirts on the nuts, and accurately ground keys that insure a pressure-tight seat.

All of these factors have a very important bearing upon installation and maintenance costs, so do not over-look them when you order YOUR Stops. Specify MUELLER and be sure of long trouble-free service.

MUELLER CO.

DECATUR ILLINOIS

Factories: Decatur, Ill., Chattanooga, Tenn., Los Angeles, Calif., Sarnia, Ont.
Branches: New York and San Francisco

"CHEAP"

A VERY COMMON WORD IN MERCHANDISING

Webster Says of this Word

"OF COMPARATIVE SMALL VALUE"

There Is Nothing Cheap

ABOUT RED HED PRODUCTS

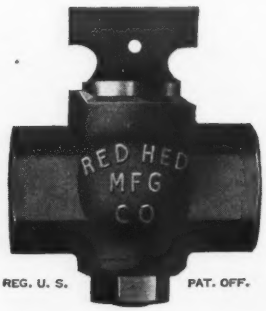


Fig. 222

CORRECT DESIGN—HAND GROUND-VIRGIN METAL
MADE BY SKILLED NEW ENGLAND WORKMEN
IN EVERY WAY

DEPENDABLE

RED HED MFG. CO.

Makers of

RED HED BRASS GOODS FOR WATERWORKS

368 CONGRESS STREET, BOSTON, MASSACHUSETTS

RESERVE STRENGTH

Fig. 883
Double Disc
Parallel Seat

—*makes ordinary duty easy for a Jenkins*

STRENGTH is emphasized in making Jenkins Iron Body Gate Valves for water works service. In both the Solid Wedge and the Double Disc Parallel Seat valves are many superior features that build up strength . . . that make a "Jenkins" capable of handling ordinary duty with ease. The result is longer valve life and less maintenance. This great reserve strength also enables a "Jenkins" to carry-on even if extraordinary strains are encountered.

When you need Iron Body Gates make your selection from the Jenkins Catalog. A special 32 page section gives you comprehensive data on Iron Body Gates in sizes from 2 inches to 48 inches; Cast Steel Gates; Electrically and Hydraulically Operated Gates; Indicator Posts; Floor Stands and Gearing arrangements. Use this Book to save time and safeguard your valve investment.

JENKINS BROS., 80 White Street, New York, N.Y.; 510 Main Street, Bridgeport, Conn.; 524 Atlantic Avenue, Boston, Mass.; 133 No. Seventh Street, Philadelphia, Pa.; 822 Washington Boulevard, Chicago, Ill.; JENKINS BROS., Limited, Montreal, Canada; London, England.

Jenkins Valves

BRONZE—IRON—STEEL SINCE 1864

Lithographed on Stone by James E. Allen for U. S. Pipe & Foundry Co., Copyright 1937, U. S. Pipe & Foundry Co.

THE job calls for a corrosion-defying material with great strength to cope with a variety of stresses. Cast iron pipe is specified as a matter of course. But even the simplest routine installation may encounter unforeseen stresses in years to come and be saved from untimely failure by these safety factors of cast iron pipe. Century-old cast iron mains have survived vastly changed conditions and stresses. Advances in foundry technology and metallurgical control—represented by Super-de Lavaud Pipe, centrifugally cast in a metal mold *without chill*—have considerably enhanced the stress-strengths of cast iron pipe. The impact strength, for example, of Super-de Lavaud Pipe is extraordinary.

SUPER-DE LAVAUD CENTRIFUGAL CAST IRON PIPE

U. S. Pit Cast Pipe
U. S. Mechanical Joint Pipe
U. S. Flexible Joint Pipe
Alloy and Gray Iron Castings
U. S. Threaded Cast Iron Pipe
U. S. Ni-Resist Cast Iron Pipe
U. S. Cast Iron Culverts
U. S. Cast Iron Roof Plates

U.S. cast iron PIPE

Cast iron and alloy cast iron pipe centrifugally or pit cast—for water works, gas, sewerage and drainage service as well as industrial uses involving corrosives.

U. S. Pipe & Foundry Co.
BURLINGTON, N. J.

Foundries and Sales Offices throughout the U. S.

The Journal of the New England Water Works Association

is a quarterly publication, containing the papers read at the meetings, together with reports of the discussions. Many of the contributions are from writers of the highest standing in their profession. It affords a convenient medium for the interchange of information and experience between the members, who are so widely separated as to find frequent meetings an impossibility. Its success has more than met the expectation of its projectors; there is a large and increasing demand for its issues, and every addition to its subscription list is a material aid in extending its field of usefulness.

All members of the Association receive the JOURNAL for two dollars per annum which sum is included in their annual dues; to all others the subscription is four dollars per annum.

TO ADVERTISERS

THE attention of parties dealing in goods used by Water Departments is called to the JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION as an advertising medium.

Its subscribers include the principal WATER WORKS ENGINEERS and CONTRACTORS in the United States. The paid circulation is **1100** COPIES.

Being filled with original matter of the greatest interest to Water Works officials it is PRESERVED and constantly REFERRED TO BY THEM, and advertisers are thus more certain to REACH BUYERS than by any other means.

The JOURNAL is not published as a means of revenue, advertisements being inserted solely to help meet the large expense of publication.

ADVERTISING RATES

One page, one year, four insertions	Eighty Dollars.
One-half page, one year, four insertions	Fifty-six Dollars.
One-fourth page, one year, four insertions	Thirty-six Dollars.
One-twelfth page (card), one year, four insertions	Twelve Dollars.
One page, single insertion	Forty Dollars.
One-half page, single insertion	Thirty Dollars.
One-fourth page, single insertion	Twenty Dollars.

Size of page, 4½ x 7¼ net.

A sample copy will be sent on application.

For further information, address the Advertising Agent,

(Miss) MARCELLA SACHS,
613 STATLER BUILDING,
BOSTON, MASS.

LEADITE

Trade Mark Registered U.S. Pat. Office

ISN'T IT TRUE?

In the purchase of a household commodity, a luxury or a piece of industrial equipment,—the purchaser is either consciously or unconsciously influenced by the Trade Name of the article,—or the name of its maker,—and rightly so.

Those Trade Names or Firm Names which are well known,—which have weathered the storms and which have been recognized as "symbols" of Quality and Integrity—are usually the ones most frequently remembered and specified by purchasers.

For example, let us consider the name LEADITE, as related to bell and spigot water main construction. . . . This name has been associated with a dependable, quality product for more than 35 years. . . . It is known and remembered by Water Works Men most everywhere in the United States (and many overseas countries).

So,—after all, there's real significance attached to a TRADE OR FIRM NAME;

In fact, someone wisely said years ago that "A PRODUCT IS ONLY AS GOOD AS THE REPUTATION OF ITS PRODUCER."

The Pioneer Self-Caulking material for c.i. pipe.

Tested and used for over 35 years.

SAVES AT LEAST 75%

No Caulking